

# METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 50 No. 297

JULY, 1954

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# METALLURGIA

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INCORPORATING THE METALLURGICAL ENGINEER

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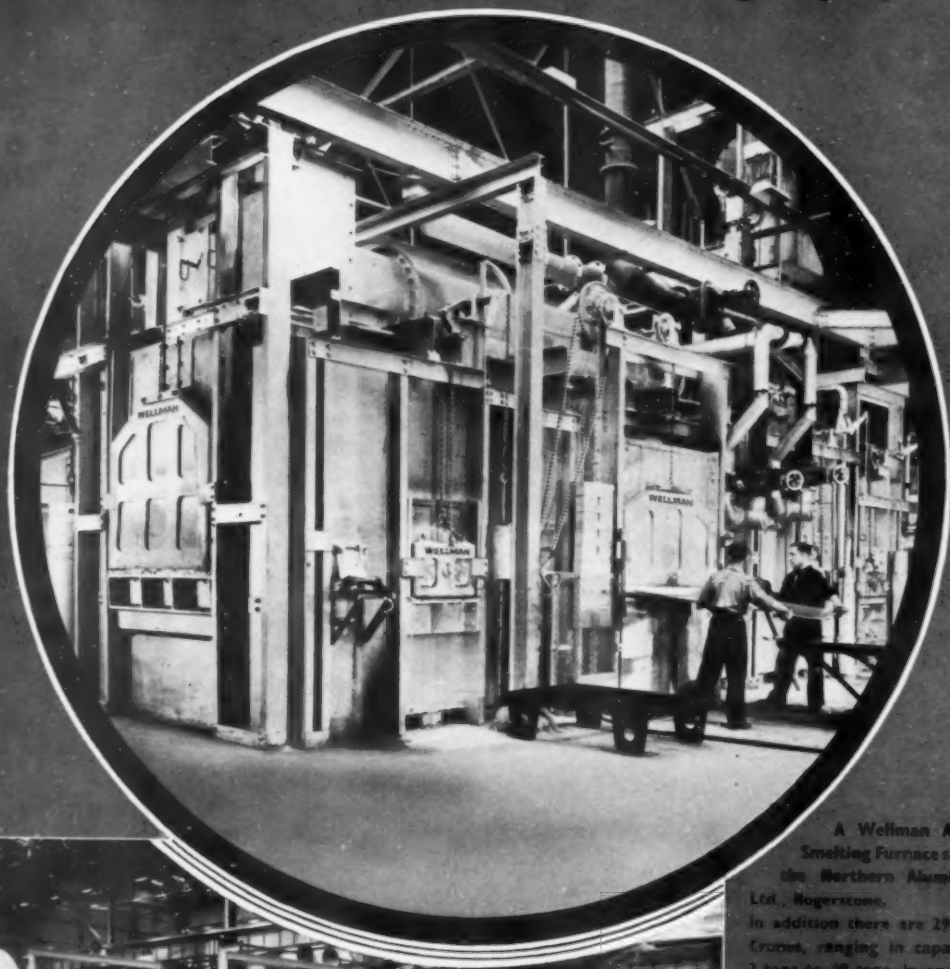
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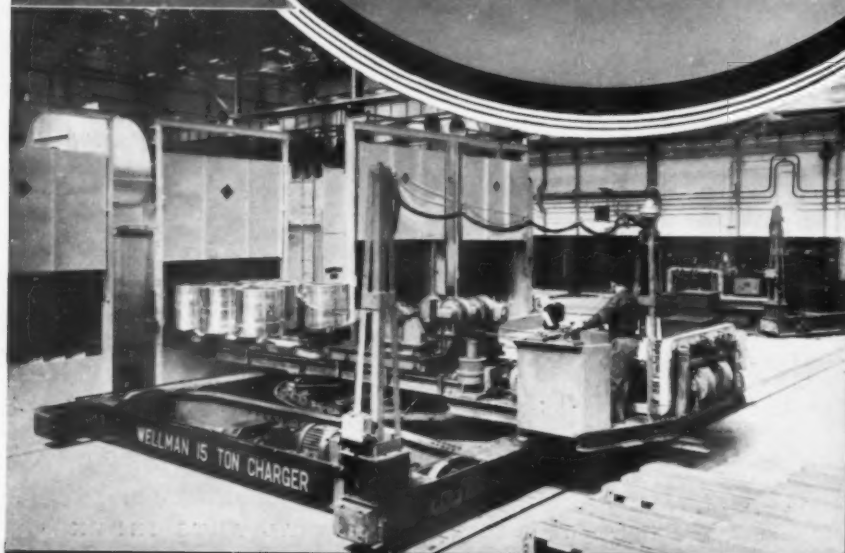
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# METALLURGIA

THE BRITISH JOURNAL OF METALS  
INCORPORATING THE "METALLURGICAL ENGINEER"

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## Post-Graduate Training

AT a conference on "Industry and the Universities," held in 1949 under the auspices of the Federation of British Industries, the suggestion was made that post-graduate courses should be organised for those men likely to be concerned with the more technical aspects of industry. Such a proposal was a logical outcome of a realisation that it is vital that Britain should strengthen her ability to make prompt application of advances in scientific knowledge to the processes of industrial production. Most graduates whose work in industry demands a broad understanding of the technical and economic aspects of metallurgical processes are conscious of the need to keep in touch with new developments in metallurgical theory and practice. Because information on recent developments is widely dispersed, and sometimes obscure, they often find it difficult to maintain this contact while preoccupied with the day-to-day requirements of their particular jobs. Similarly, graduates who are working in specialised branches of metallurgy, and perforce concentrating their interest and effort in a narrow field, cannot easily keep abreast of the rapid advances taking place in other subjects allied to their speciality. It is important that they should do this, because advances in one field of knowledge can often provide the key to the problems of another. To the industrial scientist, therefore, a period of further training at a university, not only brings the benefit of a renewed study of his specialised interests at an advanced level, but also offers the opportunity to gain a wider view and deeper understanding of his science.

The suggestion of the F.B.I. was supported in a practical way by the University Grants Committee, who, appreciating its importance to the country, decided to make available to a select number of university departments the funds necessary to enable them to inaugurate and conduct post-graduate courses in specific technological subjects. So it was that Birmingham University was asked to undertake the provision of post-graduate courses in metallurgy, chemical engineering, and certain aspects of mechanical engineering. The metallurgy course has now entered a new phase, in that, in addition to the Diploma in Post-Graduate Studies (Metallurgy), it is now possible for those who already hold a Bachelor's degree to qualify for the award of the degree of M.Sc.

In devising the course, further details of which are given elsewhere in this issue, the Department of Industrial Metallurgy had in mind that it should cater for men with the necessary qualifications who had had some experience—preferably two years or more—in the metallurgical industries, and who were rising to a position of importance and responsibility, and that it should provide facilities for specialised studies in the field in which they had found their interest to lie. There seemed to be less tendency in Germany and the United States—two countries in industrial and commercial competition with the United Kingdom—to hustle technologists

through the study course for their first degree, a three-year undergraduate course being exceptional. To the extent that the post-graduate course has the effect of making a three-year course into a four-year one, it might be considered that it puts U.K. students on a par with those in Germany and the U.S.A. It is believed that it does much more than that, as the original technical training of the student, combined with his experience in industry, enables him to obtain much greater benefit than he would on attending such a course immediately after graduation.

When the scheme was first discussed it was suggested that the numbers taking the course each year might reach twelve when it became established, and the present staff could cope with such numbers. Moreover, should the demand exceed that figure, additional funds would be made available by the University Grants Committee. The need is realised, the facilities are available—what use is being made of them? Last year the students totalled seven, including representatives of Commonwealth and other overseas countries.

Whilst it is possible for a student to enrol for the course privately, it was envisaged that the majority would be sponsored by their employers. However much the latter appreciate the possibilities of the scheme, they are unlikely to sponsor other than their most promising employees, and in so doing they are depriving themselves, for twelve months, of the services of useful members of the staff. This is a situation which has to be faced, and although the difficulties are aggravated by the shortage of metallurgical graduates, a number of employers are taking a long-term view.

The suggestion has been made that this difficulty might be overcome by the adoption of short courses of, perhaps, three weeks duration. It is felt, however, that this would be a very poor second best, because, apart from the fact that it would need a succession of three-week courses—at suitable intervals—to deal with anything like the number of technical subjects included in the present syllabus, there would be the loss of that less tangible, but no less important, benefit to be derived from spending a year or so in a university atmosphere. This is particularly important in the case of those students who have not previously had this opportunity.

Provision has been made for some of the students to live in a university hostel, along with research students and students from other graduate schools, and the experience of meeting other students and members of staff, of hearing and discussing their views, and of taking part in the cultural and social life of the university may have a lasting and beneficial effect. The qualifications for taking a position of major responsibility in industry are partly technical and partly personal. The university can make a substantial contribution in both fields, and the authorities concerned have been gratified to learn from employers that students have returned to them, not only with improved technical knowledge and judgment, but also with greatly enhanced personal qualities.

## Birthday Honours List

The names of those honoured by Her Majesty the Queen on the occasion of her official birthday on June 10th, included the following:—

### KNIGHTHOOD

- ARNOLD A. HALL, Director, Royal Aircraft Establishment.  
 FREDERICK SCOPES, President, Joint Iron Council.  
 FRANCIS E. SIMON, C.B.E., Professor of Thermodynamics, University of Oxford.  
 ALEXANDER R. TODD, Chairman of the Lord President of the Council's Advisory Council on Scientific Policy.

### K.B.E.

- IVAN A. R. STEDEFORD, Chairman and Managing Director, Tube Investments, Ltd.

### C.B.E.

- T. E. GOLDUP, Director, Mullard, Ltd.  
 F. H. HARRISON, Director of Equipment and Stores, Ministry of Supply.  
 H. G. HERRINGTON, Managing Director, High Duty Alloys, Ltd.  
 W. I. JONES, Director-General of Research, National Coal Board.  
 V. A. PASK, Chief Engineer, Headquarters of the British Electricity Authority.  
 A. E. RUSSELL, Director and Chief Designer, Bristol Aeroplane Company, Ltd.  
 H. TONGUE, Chief Engineer, Atomic Energy Research Establishment.  
 B. B. WINTER, Director of Engineering, Rootes, Ltd.

### O.B.E.

- R. ALEXANDER, Assistant Works Manager, Capenhurst, Department of Atomic Energy.  
 L. R. BARRETT, M.B.E., Assistant Director, Ministry of Supply.  
 H. BATEMAN, Assistant Director of Guided Weapons (Australia), Ministry of Supply.  
 J. B. BROWN, Manager, Gun Mounting Department, Vickers-Armstrongs, Ltd.  
 F. M. COLEBROOK, Senior Principal Scientific Officer, National Physical Laboratory.  
 S. CONSTANTINE, Director and General Manager, James Dixon & Sons, Ltd.  
 D. A. EVANS, Assistant Director of Aircraft Engineering, Air Ministry.  
 E. W. FIELD, Managing Director, H. W. Ward and Company, Ltd.  
 F. A. FOORD, lately Chief Technical Adviser to Principal Director of Engine Research and Development, Ministry of Supply.  
 F. GRIMSHAW, General Works Engineer, Leyland Motors, Ltd.  
 W. M. HAMPTON, Technical Director and General Manager, Chance Bros., Ltd.  
 F. C. LANT, Deputy Chief Fuel Engineer, Ministry of Fuel and Power.  
 M. J. LITHGOW, Chief Experimental Test Pilot, Vickers-Armstrongs, Ltd.  
 G. M. L. LOGIE, Shipyard Manager, Swan, Hunter and Wigham Richardson, Ltd.  
 T. W. MATHIAS, General Operations Manager, Shell-Mex and B.P., Ltd.

W. PARKIN, Superintending Examiner, H.M. Patent Office, Board of Trade.

C. H. PERRY, Chief Constructor, Admiralty.

F. S. SNOW, Principal, Frederick S. Snow and Partners.

W. L. WILSON, Superintending Engineer, Ministry of Works.

### M.B.E.

- C. E. ADDIS, B.E.M., Assistant Works Manager, Bulpitt & Sons, Ltd.  
 E. BALLARD, lately Senior Foreman of Engineer Branch, Admiralty.  
 J. BARNES, Manager, Metal Pattern Shop, G. Perry & Sons, Ltd.  
 M. J. BARRETT, Chemical Plant Manager, British Titan Products Company, Ltd.  
 D. L. BROWNLOW, Director and Chief Engineer, Mirrlees, Bickerton & Day, Ltd.  
 M. L. BURGAN, Experimental Officer, Royal Aircraft Establishment.  
 R. H. J. CARY, Senior Experimental Officer, Radar Research Establishment.  
 E. CRADDOCK, Director and General Manager, West Hunwick Silica and Firebrick Company, Ltd.  
 E. W. CROSS, Chief Executive Officer, Atomic Weapons Research Establishment.  
 E. CROSS, M. M., J.P., Personnel Manager, Richard Thomas and Baldwins, Ltd.  
 W. J. DALLAS, Head Outside Engineer and Dock Superintendent, Yarrow and Company, Ltd.  
 D. J. P. DAVIES, Superintendent of Works, Ministry of Works.  
 P. F. ELLIS, Training Superintendent, National Oil Refineries, Ltd.  
 F. MCWILLIAM GALBRAITH, Technical Officer (Engineering), Ministry of Labour and National Service.  
 W. MCARTHUR GALL, Manager, Barry Graving Dock and Engineering Company, Ltd.  
 R. E. HALL, Assistant Manager, T. R. Dowson and Company, Ltd.  
 F. R. IMISON, lately Chief Personnel Manager, Bristol Aeroplane Company, Ltd.  
 W. B. LAWRIE, Factory Inspector, Class 1B, Ministry of Labour and National Service.  
 S. H. LINES, General Works Manager, A. C. Cossor, Ltd.  
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 A. I. F. SIMPSON, Senior Engineer, The General Electric Company, Ltd., Coventry.  
 J. SMITH, Industrial Relations Officer, Lockheed Hydraulic Brake Company, Ltd.  
 L. F. SMITH, Company Secretary, Longford Engineering Company, Ltd.  
 E. N. SOUTHALL, Director, Joseph Westwood and Son (Cradley Heath), Ltd.  
 H. J. TABOR, Senior Experimental Officer, Royal Mint.  
 G. TEE, Works Manager, Fairey Aviation Company, Ltd.

*Continued on page 12*

# The Metallurgy of Welding

By W. I. Pumphrey, M.Sc., Ph.D.\*

*Spectacular advances have been made in welding practice in recent years, and the processes in use today are many and varied. They can, however, be broadly divided into fusion and fusionless types, and in this article attention is directed to the metallurgical changes taking place during welding and to their effect on the properties of the weld metal and the heat-affected zone of the parent metal.*

ONE of the most noticeable features of the growth of the application of welding has been the increasing tendency for the welding engineer and the metallurgist to collaborate in the investigation of any particularly troublesome welding problem. This close collaboration over the past twenty years or so, together with the great amount of research work which has been done in that time to establish the metallurgical principles involved in welding, has been responsible for many of the spectacular advances which have been made in welding practice, and has provided the basis for still greater developments in the future. The art of joining two pieces of metal together by hammer welding, however, has been practised for centuries, and in this respect welding may be said to be one of the most ancient of the metallurgical arts. The process of forge welding which was discovered many centuries ago is still practised, although its use is now confined, very largely, to the blacksmith's shop, and the chart shown in Table I<sup>†</sup> gives some indication of the great variety of welding processes in use to-day. Despite the wide diversity of modern welding processes, they can, for convenience, be divided into two broad groups. The first group consists of those processes in which melting occurs between the abutting faces at some stage during the welding operation, while the second comprises those pressure welding processes in which melting of the faces to be joined does not occur. This division, while convenient, is, of course, purely arbitrary, and there are borderline processes, such as spot welding, in which melting does not necessarily occur, although, when such processes are not designed specifically as fusionless processes they may, for convenience, be grouped with the fusion welding processes.

\* Research Manager, Murex Welding Processes, Ltd.

## FUSION WELDING

Gas welding and arc welding (whether gas-shielded arc or metal arc) are, perhaps, the best known fusion welding processes, and the great bulk of present day welding is carried out by one or other of these methods.

From the metallurgical aspect a fusion welding operation embodies a number of metallurgical operations in miniature, in that it involves melting metal—usually under a slag cover—refining or purifying the metal while it is molten, and adding to it the elements necessary to develop the desired properties in the final solidified metal. Following this, the metal must be cooled at a controlled rate in order to secure desirable transformational effects where such effects can occur, and, finally, the solidified metal must be capable of being heat treated, worked and machined in exactly the same way as any metal casting or ingot of more massive size. The metallurgical problems associated with the welding operation are thus those problems which are encountered in all metallurgical operations which involve casting and working, accentuated, perhaps, by the small scale of the operation.

In a fusion welding process, the edges of the pieces to be united are melted and fused together, and additional metal is usually supplied to the pool of molten metal at the joint by means of a suitable filler rod or electrode core wire. A portion of the parent metal is always melted and mixed with the filler metal, and in certain instances no additional filler metal is required to complete the joint. Because of the rapidity with which most metals oxidise at high temperatures, they must be protected from the oxygen in the atmosphere during welding. In the oxy-acetylene process this protection is normally afforded by a flux which is applied to the surfaces to be joined before fusion occurs; in metal arc welding the flux is attached in rigid fashion to the

TABLE I.—MODERN WELDING METHODS AND PROCESSES

Arc Welding				Gas Welding	Thermit Welding	Resistance Welding	Forge Welding	Flow Welding	Induction Welding	Brazing
Metal Electrode		Carbon Electrode								
Shielded	Unshielded	Shielded	Unshielded							
Shielded Metal Arc Welding Impregnated Tape Metal Arc Welding Atomic Hydrogen Welding Inert-Gas-Shielded Metal Arc Welding Submerged Arc Welding Shielded Stud Welding	Bare Wire Metal Arc Welding Stud Welding	Shielded Carbon Arc Welding Inert-Gas-Shielded Carbon Arc Welding	Carbon Arc Welding Twin Carbon Arc Welding	Oxy-Acetylene Welding Air-Acetylene Welding Oxy-Hydrogen Welding Pressure Gas Welding	Pressure Thermit Welding Non-Pressure Thermit Welding	Spot Welding Seam Welding Projection Welding Flash Welding Upset Welding Percussion Welding	Hammer Welding Die Welding Roll Welding	Flow Welding	Induction Welding	Torch Brazing Twin Carbon Arc Brazing Furnace Brazing Induction Brazing Resistance Brazing Dip Brazing Block Brazing Flow Brazing

core wire of the electrode used for welding. Protection from oxidation may also be secured by means of an inert gas such as argon, and this means of protection is employed in the modern gas-shielded arc welding processes, where the arc, which is struck between a bare metal electrode and the work, is shielded by a blanket of argon or helium which surrounds the arc.

A fusion welding process is, in essentials, a miniature casting process, in that molten metal is deposited and caused to solidify between the cooler walls of what is, in effect, a metal mould. The fused zone of a weld is thus analogous in every respect to a casting, and those factors which influence the structure, homogeneity, properties, etc., of a casting have a corresponding influence on the properties of a weld.

The precautions which are necessary to ensure the production of sound ingots or castings are also necessary for the production of sound welds, and, as in metal refining or casting, precautions must be taken to guard against the introduction of undesirable substances (such as oxides, slag inclusions or other impurities) into the weld pool, and to make good any loss of desirable and beneficial alloying elements. The designer of flux-coated metal arc electrodes must, therefore, possess a sound working knowledge of the speed and degree of completion of the reactions which can occur between molten metals, whether ferrous or non-ferrous, and molten slags, in order that he may add to his flux coatings a sufficient balance of alloying elements to make good any loss of alloying elements from the metal to the slag during welding. A great deal of research work is being carried out at the present time which will provide the basic data on the thermodynamics of slag/metal reactions necessary for the development of new and improved electrodes.

### Metallurgical Features

From this introduction it will be clear that the metallurgical happenings during fusion welding can be considered as occurring in three stages. Firstly, those happenings which occur during the time that the weld metal is fully molten; secondly, those which occur during solidification of the weld metal; and, thirdly, those which occur when the weld is completely solid and has cooled, or is cooling, down to room temperature.

#### 1. The Molten Stage.

During the time that the weld metal is fully molten it is exposed to the same influences as any more massive quantity of liquid metal standing under a covering of flux. In addition to these influences, however, the liquid metal is exposed to the air and to the atmosphere surrounding the weld pool during its passage through the arc, and may absorb a not inappreciable quantity of such gases as oxygen, nitrogen and hydrogen. Such gases, if absorbed, are most generally ejected from solution when the weld metal solidifies.

#### 2. The Solidification Stage.

The second stage in the consideration of the metallurgical happenings during fusion welding involves the period during which the molten weld metal is solidifying. During this stage much of the gas which may have been taken into solution during the time that the metal was fully molten is ejected from solution, although any compounds, such as oxides and nitrides, formed between the gas and the metal may remain in the metal unless, as occurs during fluxed fusion welding, they are removed into a flux layer on the surface of the metal.

The effects produced on weld metal by a gas which enters into solution in the molten weld metal and which is later ejected from solution as the metal solidifies are not simple and, depending upon the metal and the gas, can often appear to be contradictory. Thus, in the welding of aluminium the solution of hydrogen in the molten weld metal can have the harmful effect of causing porosity, but it can also have the beneficial effect of decreasing hot cracking by forcing liquid metal into the tears or cracks which form between the growing dendrites and so sealing them and preventing their further extension.<sup>2</sup> Again, the presence of nitrogen in steel weld metal increases the hardness and tensile strength of the steel, but decreases its ductility and tends to embrittle the material. The effect of hydrogen on ferrous weld metal calls for special mention, and will be considered in a later section of this article.

All metals solidify progressively in a dendritic manner and, if the films of liquid which exist between the growing dendrite arms prior to complete solidification are unable to withstand the contractional stresses to which they are subjected during the solidification of the weld metal, the dendrites will tear apart, giving rise to cracks which are known to the welder as "hot cracks." The composition of the metal, which governs its mode of solidification in large measure, determines its susceptibility to hot cracking. Thus, certain aluminium alloys and certain fully austenitic steels are very susceptible to hot cracking, while the majority of the mild steels are largely free from this defect. The tendency of any metal to hot cracking is, however, greatly increased by the presence within it of phases which are of lower melting point than the bulk of the metal, and which exist in liquid form at the crystal boundaries long after the crystals themselves have become solid. The presence of an undue proportion of iron sulphide in mild steel is particularly harmful in this respect, and care is usually taken in the design of a mild steel metal arc electrode to balance the flux so that any sulphide which forms during welding is manganese sulphide and not iron sulphide, which forms a low melting point eutectic with iron.

#### 3. The Solid Stage.

It is appropriate now to consider the factors which govern the structure of the final solid weld, and of the surrounding area. In any fusion weld considerable heat must be applied to the junction between the two component portions for melting to take place. After local melting has occurred, the metal then cools down gradually to room temperature. During the deposition of the weld metal, heat is conducted from the weld pool into the body of the base metal and, after the weld has been made, the cooling of the weld takes place very largely by conduction of the heat away from the weld area into the unheated parts of the plate. The material surrounding the weld thus passes through a similar heating and cooling cycle to the weld metal itself, the maximum temperature attained at any one point during this cycle depending on the distance of the point considered from the fusion zone.

Points remote from the fusion zone are raised in temperature but little during the welding operation, and so remain structurally unaltered as a result of the welding. The structure at points nearer the weld is, however, affected by the heating and cooling cycle obtaining at such points during welding, the degree of alteration in

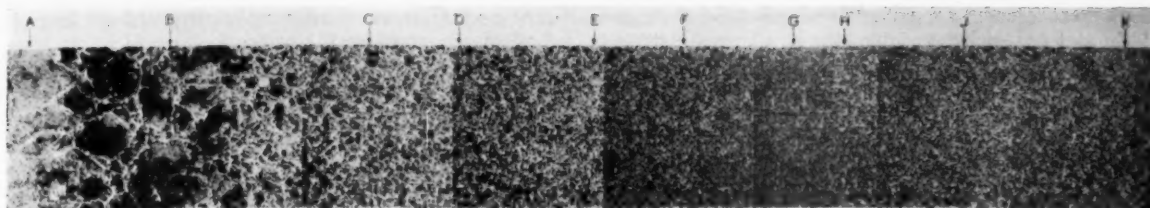


Fig. 1.—Section through fusion weld in plain carbon steel containing 0.3% carbon. Etched by immersion in 3% nital followed by immersion in 4% picral.  $\times 100$

Reduced  $\frac{1}{2}$  linear in reproduction

the structure being dependent upon the maximum temperature attained at the point considered.

The alteration in the structure of the base metal adjoining the fusion zone after completion of the weld cycle is illustrated in Fig. 1 which shows a section through a fusion weld in a plain carbon steel containing 0.3% carbon. The gradation of structures outwards from the fusion zone in Fig. 1 illustrates the effect of heat flow from the weld and is illustrative of the effects which can occur during the welding of any metal, whether ferrous or non-ferrous. The region surrounding the weld over which there is a detectable alteration in the structure and properties of the base metal as a result of the welding operation is known as the heat-affected zone of the weld, as distinct from the fusion or melted zone.

The structures in Fig. 1 range from the cast structure at point A to the structure of the plate, unaffected by the welding operation, at point K. In any fusion weld, the fusion zone has a cast structure when solid, but in fusion welds made using filler rods or coated electrodes, the fusion zone is somewhat heterogeneous, both in composition and structure, since it is composed of filler metal melted and mixed with base metal.

The coarse grained structure near the weld junction at points B, C, and D in Fig. 1 is a result of the steel being heated above the upper critical temperature and into the austenite grain coarsening range of temperatures, and the Widmanstätten structure observable in the coarsened area in the region of point B is similar to that generally observed in steel castings and in overheated structures.

At points such as E, F and G, which are further away from the fusion zone, the coarse grained structure is replaced by a particularly fine grained structure, and the fine structure in the vicinity of points F and G indicates that this region of the parent metal was heated above the upper critical temperature during some part of the welding cycle (but not sufficiently far above the upper critical temperature for grain coarsening to occur) and was then cooled fairly rapidly.

At points still further away from the fusion zone the metal was not heated above the upper critical temperature at any time during the welding cycle, and the portion between points H and J in Fig. 1 embraces locations which, during the welding operation, were heated to temperatures between the lower and the upper critical temperatures. Over the portion between H and J, full grain refinement has not occurred, although the individual pearlite areas are more finely dispersed than in the parent plate (point K in Fig. 1). In the particular weld illustrated in Fig. 1, point H marks the boundary between those portions of the plate which were, and

those which were not, heated above the upper critical temperature at any time during the welding cycle.

At locations in the region of point K, the metal was not, at any time, heated to a temperature sufficiently high to affect the basic structure of the parent plate, and the structure at K thus represents the structure of the original steel plate.

A heat-affected zone is present in all metals after welding, but the structure and properties of this zone depend upon the metal which is welded and also, to some extent, on the welding process. Thus, in non-heat-treatable non-ferrous material, the heat-affected zone is largely detectable by reason of the different grain sizes within it, relative to the unaffected parent metal. With the heat treatable non-ferrous alloys the heat-affected zone is defined by the area over which a change in hardness, possibly accompanied by a change in grain size, has resulted from the welding operation.

With a non-hardenable mild steel, the most notable changes in the structure of the parent metal caused by its being heated during the welding cycle are the marked grain coarsening in the region of points B, C and D in Fig. 1 and the pronounced grain refinement in the region of points F and G.

The changes in the structure of the parent metal are essentially the same in welds made by any process, whether fusion welding or pressure welding, and the gradation of structure across any fusion weld in a non-hardenable mild steel, for example, is as shown in Fig. 2. In a weld made without fusion, the fusion zone is, of course, absent, but in all other respects the structures

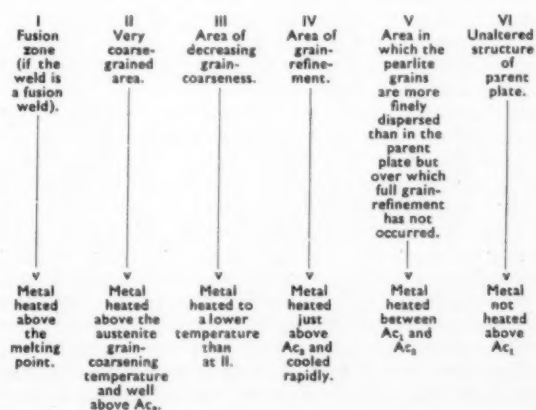


Fig. 2.—Gradation of structures across a fusion weld in a mild steel.

in the heat-affected zone of such a weld are determined by the factors which determined the structures illustrated in Fig. 1.

With any metal, the heat-affected zone and the width of the different structural regions within the zone are dependent upon the particular welding process employed. When the heating is very concentrated and melting is rapid, as in arc welding, the heat-affected zone is narrow, and the different structural regions within the zone are close together. When the heat is not so concentrated (as may occur in oxy-acetylene welding), the heat-affected zone is relatively wide, and there is a more gradual transition of metallographic structures within the zone.

### Hard Zone Cracking

As already mentioned, in the welding of steel the base metal adjacent to the weld junction is heated to temperatures above the upper critical temperature during the welding cycle and is cooled down rapidly from such temperatures after completion of the weld. In the welding of low carbon steel (or the non-heat-treatable non-ferrous metals) the heating and cooling cycle associated with welding, although it has a pronounced effect on the microstructure, has but little effect on the hardness distribution across the heat-affected zone of the weld, because the base material is non-hardenable. With those steels, however, which have a tendency to air harden, local heating above the upper critical temperature into those ranges of temperature where the metal is wholly austenitic in structure, followed by rapid cooling, causes the steel to harden locally by the ordinary austenite to martensite transformation mechanism.

The transformation of austenite to martensite is accompanied by a considerable volume expansion, and if the material is unable to accommodate the resultant stresses cracking can occur. This condition is considerably aggravated if hydrogen is present in the arc atmosphere surrounding the weld pool and weld area, since hydrogen is readily soluble in austenite and is taken into (or remains in) solution in those portions of the weld which are in the austenitic condition. The solubility of hydrogen in ferrite or martensite, however, is lower than in austenite and, therefore, as the weld cools and the austenitic areas transform to martensite, the hydrogen dissolved in the austenite is forced out of solution and tends to accumulate, under pressure, at any discontinuity within the internal structure of the steel. The resulting internal stresses, coupled with the transformation stresses, greatly aggravate any tendency to local hard-zone cracking.

The transformation stresses may be minimised by preheating a hardenable steel before welding to an adequately high temperature so that, after completion of welding, the welded structure cools down sufficiently slowly to cause the austenitic areas to transform to soft pearlite and not to hard martensite. Adequate preheating of any large structure is, however, usually impracticable, and in any event it is difficult, if not impossible, to control the cooling of a welded structure so that none of the austenite formed during welding transforms to martensite.

Since hydrogen is more soluble in austenitic material than in ferritic, it is possible to weld a hardenable steel with an austenitic electrode (with adequate preheating), so that the hydrogen which is ejected from the austenitic areas of the plate material as such areas transform to

ferrite or martensite during cooling can diffuse to and be accommodated in the weld metal which remains austenitic at both high and low temperature. This procedure is not invariably satisfactory, however, since the austenitic electrodes are relatively costly, and in any case may not develop the tensile properties required in the final weld.

### Low-Hydrogen Electrodes

The low-hydrogen electrodes were developed to overcome this difficulty. These electrodes are low in available hydrogen and their flux coatings usually contain quantities of minerals which evolve gases other than hydrogen. Such gases serve not only to shield the weld metal from hydrogen pick-up during deposition, but also to dilute any water vapour formed from slight traces of residual moisture which may be present in the coating.

Using low-hydrogen electrodes the hardenable steels may be welded, without cracking, with a considerably lower preheat than would be necessary if the conventional types of mild steel electrodes were used, and in certain instances such welds may be made without any preheating. Preheating is, however, usually advantageous to minimise undesirable thermal hardening when welding the hardenable steels, since the absence of hydrogen from the arc atmosphere does not inhibit the austenite to martensite transformation which can occur in a hardenable steel when it is cooled down to room temperature from a temperature at which it is completely austenitic.

The low-hydrogen electrodes were developed for the welding of the medium and high tensile steels but, because they tend to minimise porosity and grain boundary unsoundness caused by the presence of hydrogen in the weld metal, these electrodes, when used for the welding of mild steels, can produce welds having good mechanical properties, particularly at low temperatures. The degree of preheating necessary when welding heavy mild steel sections is also less when low-hydrogen electrodes are used than when the welding is effected with more conventional electrodes.

Low-hydrogen electrodes appear to have certain advantages in the welding of free machining steels high in sulphur, and for the welding of steels which are to be enamelled after welding. Conventional mild steel electrodes often give a somewhat porous deposit when used for the welding of the high sulphur content free machining steels, this porosity being due to the formation of gaseous compounds of sulphur with hydrogen. The exclusion of hydrogen from the arc atmosphere by the use of low-hydrogen electrodes decreases the tendency for such compounds to form.

Mild steel components welded with mild steel electrodes which are not of the low-hydrogen type occasionally develop pits and black flecks on an enamelled surface laid over the weld. This is said to be a result of hydrogen diffusing out of the weld and weld area for some period of time after the conclusion of welding. Such defects may be overcome by stress relieving the welds before enamelling, and so accelerating the removal of hydrogen, but it has been observed that such stress relieving is unnecessary if low-hydrogen electrodes are used for the welding.

The benefits attendant upon the use of low-hydrogen electrodes depend upon as complete an absence as

possible of moisture and other potential sources of hydrogen from the coating. Since the normal ingredients and binders in any electrode coating contain water of crystallisation, it is necessary to bake the low-hydrogen electrodes at a high temperature during manufacture to remove, as far as possible, all free and combined moisture. Such treatment, by simple chemical laws, renders the electrode somewhat unstable in respect of moisture pick-up, and low-hydrogen electrodes generally tend to absorb moisture in storage. To obtain the best results with the low-hydrogen electrodes, such moisture must be removed by drying the electrodes at a suitable temperature before use.

### The Effect of Dilution

It is appropriate now to consider the effect of the welding operation on the composition and structural make-up of the solid weld metal. As mentioned earlier, in fusion welding the weld metal is exposed to the same chemical and metallurgical changes as are involved in the manufacture and casting of metal, with the added complication that in a fusion weld the metal of the weld is very largely diluted with metal melted from the parts being joined together. Again, because of the high temperatures involved in welding, there is usually an appreciable loss of the more easily oxidised or volatilised elements from the weld pool during the welding operation. Thus, for example, a considerable loss of magnesium from the deposited weld metal occurs during the arc welding of aluminium-magnesium alloys, and an appreciable part of the carbon is lost during the metal arc welding of the carbon steels. These two effects—dilution of the weld metal by the parent material, and loss of alloying elements from the weld metal—are, perhaps, the principal factors in determining the success or failure of any welding operation, and the composition of the deposited weld metal must compensate for any harmful occurrences introduced by these two effects.

Except with those alloys, however, which contain such readily volatilised or oxidised elements as magnesium or zinc, the ill effects due to loss of alloying elements from the weld metal and parent metal by volatilisation or oxidation are less pronounced than those introduced by dilution effects. The study of dilution effects in weld metal, unfortunately, is complicated by the fact that such effects are largely dependent upon the welding conditions, and on such non-metallurgical factors as the type of joint preparation employed. Thus, a change in the size of electrode or in the welding current used, or a variation in the length of the welding arc, can greatly alter the degree of dilution of the weld metal by the parent plate material. Again, the degree of preheating before welding also influences the dilution—the higher the preheating temperature the greater the amount of dilution which takes place. Although an exact study of the degree of dilution during welding is fraught with many complications, the effects of dilution are readily observable and usually most pronounced, especially in the welding of the stainless steels and irons, and the subject of the effects of dilution in the welding of these materials is of such practical importance that it is worth some attention at this point.

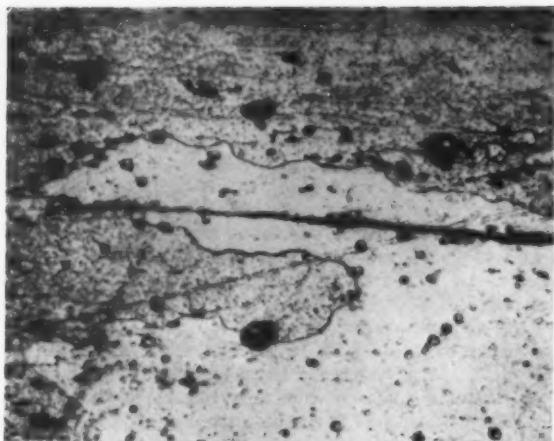
### Sigma-Phase Formation

Austenitic steels of the 18/8 type are normally not wholly austenitic at room temperature, but contain some percentage of ferrite. If such steels are to be

exposed, in service, to temperatures of the order of 650°C. for any length of time, their ferrite content must be carefully controlled, by control of the composition, since at such temperatures the ferrite islands in 18/8 steel can change to the hard and brittle *sigma*-phase, with a consequent drop in the impact strength of the steel. Since the transformation to *sigma*-phase is permanent, any such brittleness persists even when the steel has cooled down to room temperature. These considerations apply to weld metal as well as to wrought material and hence, to avoid *sigma*-phase formation in any austenitic weld metal which is to be exposed to temperatures of the order of 650°C. in service, the composition of the deposited weld metal must be so balanced that its structure contains but little ferrite to transform in this way. It might fairly be asked here why the weld should not be made with wholly austenitic material of the 25/20 type, and so be free from any possibility of *sigma*-phase formation in service. Unfortunately, however, as mentioned earlier, the wholly austenitic weld metals are somewhat susceptible to hot cracking, and a small proportion of ferrite in their structure is necessary to counteract this susceptibility. For the welding of the 18/8 and similar stainless steels, therefore, the weld metal should contain an adequate proportion of ferrite to prevent the occurrence of hot cracking (say 5-10% of ferrite), but not so much ferrite that the metal is unduly embrittled if it is maintained for any length of time in that range of temperatures in which ferrite transforms to *sigma*.

These considerations have led to the recent development of the ferrite-controlled austenitic electrodes, in which the composition of the deposited weld metal is so controlled that the weld metal is of an appropriate, and known, ferrite content. In the selection of a suitable ferrite-controlled electrode for any particular welding operation, however, some thought must be given to the occurrence of dilution effects during welding, since any excessive dilution or contamination of the weld metal by the parent material can completely nullify the use of a ferrite-controlled electrode. Thus, for example, such elements as silicon, niobium, molybdenum and titanium, which tend to promote the formation of ferrite in the austenitic steels, increase the susceptibility of such steels to *sigma*-phase formation, and, if the parent material contains any one of these elements, any pick-up by the weld metal will promote the tendency for ferrite to form in the weld and increase the susceptibility to *sigma* embrittlement. These considerations are particularly pertinent in the selection of steels and electrodes for the welding of components, such as gas-turbine parts, which will be exposed continuously in service to particularly high temperatures. Unfortunately, too, a relatively small quantity of *sigma*-phase has a greater effect upon the impact strength of weld metal than it has upon the impact strength of wrought steel of the same composition. This is due to the fact that in wrought material the alloying elements are dispersed throughout the mass in a reasonably uniform fashion, whereas in the weld metal the natural effects of segregation which occur during solidification tend to cause any *sigma*-phase which forms at a later stage to be concentrated, principally, at the crystal boundaries, so increasing its harmful effect on the impact properties of the steel.

When there is any danger of pick-up of ferritisers by the weld metal during the welding of a stainless steel



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Fig. 3.—Etched section across the interface of a pressure weld between two sheets of an aluminum-magnesium-silicide alloy to D.T.D. 423. (After Tylecote and West.)  $\times 250$

component designed for service at high temperatures, the electrode selected for the welding operation must be such that the deposited weld metal can accommodate any pick-up without developing an unduly high ferrite content and, in consequence, without becoming unduly embrittled at service temperatures in the *sigma*-phase formation range.

#### Intergranular Corrosion

It is appropriate to mention here that the difficulties which were encountered during the early days of stainless steel welding, due to the corrosion effects associated with the intergranular precipitation of carbides rich in chromium, have been overcome by the employment of suitable stabilising agents in the parent material and weld metal. By themselves forming stable carbides, the stabilising elements effectively prevent any intergranular precipitation of chromium carbide, and the consequent removal of chromium from the areas adjacent to the grain boundaries if the welded component is maintained for any length of time at temperatures in the carbide precipitation range, i.e., at temperatures of the order of 650° C. Stainless steel plate material especially designed to be of welding quality normally contains a small amount of titanium or niobium as a stabilising addition, while many present day stainless steel electrodes deposit weld metal containing a controlled quantity of niobium. Niobium is used as the stabilising agent in an electrode in preference to titanium because of the excessive loss of the latter element which can occur during transfer of metal containing it across the welding arc.

Although welds which are free from intercrystalline attack, even under relatively severe corrosive service conditions, can now be made in stainless steel components, the use of stabilised stainless steels and the selection of electrodes for welding such steels must be given some careful thought in the welding of components which are to be subjected to high temperatures in service, since the pick-up by the weld metal of such elements as titanium or niobium can increase the tendency for *sigma*-phase embrittlement in the weld metal if the composition of the latter is not chosen with care. It would seem, in fact, that stabilising elements,

by producing stable carbides, tend to reduce the quantity of carbon in solution in the metal, and this, in turn, reduces the austenite stability, increases the tendency for a greater proportion of the austenite to transform to ferrite at room temperature and so promotes the tendency for *sigma*-phase embrittlement at the appropriate service temperatures.

#### PRESSURE WELDING

As was mentioned earlier, the majority of the welding processes in use to-day are fusion welding processes and, although the forge welding of wrought iron is essentially a fusionless welding process, little use was made of fusionless pressure-welding processes on anything approaching a commercial scale until comparatively recently, although the principle of pressure welding was, in fact, employed nearly fifty years ago in the hammer welding of aluminium. Of recent years, however, there has been some development and use of pressure welding processes, especially for welding certain non-ferrous materials. This process, for example, has found particular application in the production of pipes and tubes from thin gauge sheet aluminium.

Pressure welding may be defined<sup>3</sup> as the making of a joint between the surfaces of a metal or alloy assembly at temperatures below that at which any fusion of the parts to be joined occurs. In the industrial application of pressure welding, two different procedures may be followed—either the temperature may be kept constant and the pressure varied, or the pressure may be maintained constant and the temperature varied. The constant-pressure method has certain practical advantages over the constant-temperature method, and is the method now most widely used for the pressure welding of aluminium and its alloys. In this method the two pieces to be joined are forced together under a fixed load, which is maintained constant during the welding cycle while the temperature of the area under pressure is raised to some chosen level and is maintained at this value for an appropriate time.

In the constant-temperature process the pieces to be joined are forced together under a suitable initial load and the temperature of the pieces under load is then raised rapidly to the required level, this temperature being maintained constant during the welding cycle. At

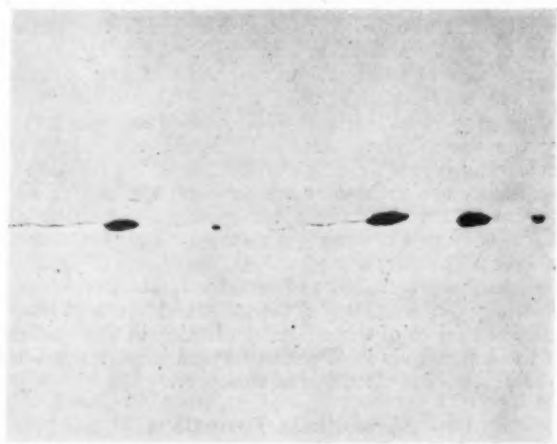


Fig. 4.—Unetched section across the interface of a pressure weld made at room temperature between two sheets of high purity aluminium.  $\times 250$

some predetermined time the heat is cut off, and a final upset load is applied and maintained as the temperature falls.

The metallurgical aspects of the pressure welding process have been studied in some detail by Tylecote,<sup>4</sup> and it would seem that, essentially, the process involves forcing the surfaces to be joined into such close contact that the atomic bonds are able to link up across the interface.<sup>3</sup> Atomic mobility increases with increase in temperature, and hence pressure welds are made more readily at high temperatures than at low. In the early studies of the process it was considered that successful pressure welding could only be carried out at temperatures in excess of the recrystallisation temperature of the metal being welded, and, in consequence, pressure welding was described as "recrystallisation" welding for some years. Recent work, however, has indicated that it is not necessary, invariably, to exceed the recrystallisation temperature in pressure welding, provided the surfaces to be joined are adequately cleaned and prepared and the applied pressure is sufficiently great. From the practical aspect, however, pressure welding is accomplished more readily, and probably more successfully, the higher the temperature of the metal.

At temperatures above the recrystallisation temperature, grain growth can take place across the weld interface. This effect is illustrated in Fig. 3<sup>5</sup> which shows the way in which grain growth has occurred across the interface in a pressure weld between two sheets of an aluminium magnesium-silicide alloy to D.T.D. 423

With any metal there is a temperature below which the amount of deformation during welding is the important factor in determining the weld efficiency in pressure welding, and above which the effects of diffusion play an increasingly important part in establishing the metallurgical bond, particularly between dissimilar alloys or materials of high alloy content, even when grain growth does not occur. With pure aluminium this "transition" temperature is approximately 250 to 260° C., while for the pressure welding of the more complex aluminium alloys temperatures of the order of 300–550° C. are employed, the higher the temperature the lower the unit pressure necessary for welding to take place.

For successful pressure welding, the mating surfaces must be as clean and free from oxide skin as possible. With certain metals, such as aluminium, which have a great affinity for oxygen it is almost impossible to obtain a surface on a sheet or plate which is free from oxide. It has been found, however, with such metals, that if the surfaces to be joined are scratch-brushed before welding, very high local pressures are developed at the tips of the minute ridges on the scratch-brushed surfaces during the welding operation, so disrupting any surface oxide film which is present and squeezing it, as the applied pressure is increased, into the hollows on the surfaces.

With metals, such as iron and copper, which are capable of taking their oxides into solid solution, the oxides present at the interface in the initial stages of pressure welding may be taken into solution at some later stage in the process or during subsequent heat-treatment. Other metals, such as aluminium however, are incapable of taking any appreciable proportion of their oxides into solid solution and in pressure welds



Fig. 5.—Unetched section across the interface of a pressure weld made at room temperature between two sheets of commercial purity aluminium.  $\times 500$

in such metals small pockets of oxide are often present along the line of the joint. This effect is illustrated in Fig. 4 which shows a section across the interface of a pressure weld made at room temperature between two sheets of high purity aluminium which contains a discontinuous line of oxide inclusions at the joint. The points at which the oxide inclusions occur in Fig. 4 are the locations of the original hollows on the mating surfaces into which the oxide inclusions were squeezed under the applied pressure.

While the section shown in Fig. 4 is illustrative of the effect mentioned, however, the more usual appearance of the interface of a pressure weld in commercial purity aluminium is as shown in Fig. 5. The structural condition of most non-ferrous materials before welding—apart, perhaps, from modifying their flow characteristics under pressure in some measure—does not appear to have any pronounced effect on their pressure welding properties, and the strength of a pressure weld in the non-ferrous alloys which have been welded by this process has been observed to be much the same as that of a sound spot weld of equivalent size in the same materials.

Pressure welds in the heat-treatable aluminium alloys, however, are reported to be more responsive to heat-treatment than spot welds. This is probably because some local fusion almost invariably occurs during spot welding, while fusion does not occur in pressure welding, and the response to heat-treatment of a cast structure is not as pronounced as that of a wrought structure.

#### Acknowledgments

The author wishes to record his indebtedness to the Directors of Murex Welding Processes Ltd., for permission to publish this article.

1 Taken from a diagram in the "Welding Handbook," 3rd edition, 1950. Published by the American Welding Society, New York.

2 D. C. G. Lees, *Jnl. Inst. Metals*, 1947, **73**, 537.

3 E. G. West, "The Welding of Non-Ferrous Metals," Chapman and Hall (London), 1951, p. 121.

4 R. F. Tylecote, *Sheet Metal Ind.*, 1949, **26**, 161. See also *Trans. Inst. Weld.*, 1945, **8**, 163; *Weld Res.*, 1948, **2**, 94r; 1949, **3**, 2r; and *Met. Ind.*, 1952, **81**, 43, 72.

5 E. G. West, "The Welding of Non-Ferrous Metals," Chapman and Hall (London), 1951, p. 250.

# Oxygen in Steelmaking

## Report of B.I.S.R.A. Conference

*Practical industrial use of oxygen in steelmaking has increased considerably in the last decade, and in this brief account of a conference organised by the British Iron and Steel Research Association, reference is made to a number of aspects of the question. Particular attention is paid to desiliconising of hot metal, oxygen lancing in the open hearth furnace, and the use of oxygen-enriched blast in the converter process.*

THE use of oxygen in steelmaking has been a topic of discussion since the days of Henry Bessemer, and has been the subject of experiment in various directions for about 50 years. Practical industrial use has, however, increased considerably during the last ten years or so, and a conference recently called by the British Iron and Steel Research Association to discuss post-war development had plenty of material to consider. The conference was under the chairmanship of Dr. T. P. Colclough, C.B.E., of the British Iron and Steel Federation (Chairman of B.I.S.R.A.'s Steelmaking Divisional Panel) with Mr. R. W. Evans, Steel Company of Wales, Ltd. (Chairman of the Steel Practice Committee) acting as vice-chairman. About 120 representatives from steelmaking firms and suppliers of oxygen and oxygen manufacturing equipment attended.

The use of oxygen in steelmaking has proved its usefulness in the United Kingdom in refining in the arc furnace; in the partial purification of pig iron before feeding to the open hearth furnace, in certain circumstances (especially where there is no active mixer); and in speeding up the refining of low carbon steels in open hearth furnaces. Since there are so few Bessemer converters in operation in Great Britain the use of oxygen for blast enrichment has made comparatively little progress here, although it is now practically standard practice on the Continent of Europe.

### Tonnage Oxygen

One of the factors which has so far limited the development of oxygen in steelmaking in this country has been that the successful applications have not led to the very large consumption which would justify substantial capital expenditure on "tonnage" oxygen plants supplying oxygen of 96-98% purity. For instance, its use for speeding up the refining of even as much as 18,000 tons of steel per week would only consume 13-15 tons of oxygen per day, which is not quite enough for a tonnage plant, but rather too much for the economic use of evaporated oxygen. One solution suggested by a representative of the British Oxygen Co., Ltd., was the establishment of tonnage oxygen plants adjacent to groups of steelworks, to which supplies could be piped. Because "engineering" demands could account for up to 30% of the total demand, he thought such generators should produce high purity gaseous oxygen. While small-scale tonnage oxygen plants could be designed to produce as little as ten tons per day, the economic benefits of large scale operation were very marked, and four times the oxygen could, for example, often be produced if capital investment were doubled. It should also be remarked that it was necessary as far as possible to maintain consumption of tonnage oxygen continuously. A low load factor was a source of expense.

In Germany, in a large number of different works



Oxygen "gun" jetting pure oxygen on to bath in open hearth steel furnace at the Steel Company of Wales, Ltd.

oxygen is used for enrichment of the blast of Thomas converters with a resulting decrease in the mean nitrogen content of the steel and its final phosphorus content. By such means, iron containing rather less phosphorus than normal can be successfully blown to a tapping temperature. With oxygen enrichment the blow is also shorter, and a higher recovery of metal is obtained from a larger addition of iron ore during the blow. The oxygen consumption is about 1,000 cu. ft./ton of steel which raises the oxygen content of the blast to 30%. Desiliconising by pre-blowing is also carried out.

At Hagen-Haspe in Germany and Espérance-Longdoz in Belgium, the nitrogen content of the blast is not merely diluted by adding more oxygen. During the final stages of blowing, the converter is blown with a mixture of oxygen and superheated steam, which of course will contain no nitrogen at all. In this way the final nitrogen content of the steel is brought below 0.0025%.

Both these "mixed blast" processes consume about 1,800 cu. ft. of oxygen per ton of steel. In a plant producing only 5 thousand tons of steel per week the oxygen demand for this purpose alone will amount to over 50 tons/day.

### The L-D Process

Another process in operation on the Continent (in Austria) is known as the "L-D" process. In this 30-ton vessels are used with no bottom tuyeres. A single jet of 98% pure oxygen is made to impinge on to the surface of the bath through a water-cooled nozzle which is introduced through the mouth of the vessel. The blast is introduced at the rate of 3,000 cu. ft./min.

at a pressure of 250 lb./sq. in. It has been suggested that this process might prove of value to the British steel industry in the near future as it offers the following advantages:—

- (1) Apart from the tonnage oxygen plant the capital cost is low.
- (2) Low-nitrogen steels may be produced without recourse to superheated steam or  $\text{CO}_2$  as blast diluents.
- (3) Irons of a chemical analysis hitherto considered quite unsuitable for either acid or basic converter steelmaking processes can be successfully refined.
- (4) Because phosphorus may be oxidised in the L-D vessel during, and sometimes substantially before, the oxidation of carbon, it offers a means whereby metal may be duplexed both for the removal of silicon and a substantial proportion of the phosphorus, without complete loss of the carbon and consequent elevation of the melting point.

It has been suggested that these or related principles might have a part to play in enabling the British steel industry to produce economically the steels low in carbon, phosphorus, sulphur and nitrogen required for continuous strip rolling, in face of the deterioration of the quality of blast furnace material and the 2.5% of sulphur which open hearth fuel oil often contains. It is understood that trials are in progress.

The conference did not hear in such detail about developments in the use of oxygen in the United States, but it was reported that at the Inland Steel Company 150 tons of oxygen were being used per open hearth furnace per day for enriching the air as well as for decarburisation. It appeared that output was greatly increased and that refractories consumption had not been unduly severe. These quantities were being used for low carbon steels and the problem of speeding the production of high carbon steels by the use of oxygen was still in the experimental stage.

#### Oxygen Lancing in the Open Hearth

Among applications in the United Kingdom, the Conference heard a description by DR. A. J. KESTERTON of the method of decarburisation at the Abbey Melting Shop of The Steel Company of Wales, Ltd. Because of the method of charging it is inconvenient to put the oxygen lance in from the front, and a specially designed water-cooled gun is therefore lowered through the centre of the roof of the furnace, opposite to the tap hole. Evaporated oxygen is blown through the gun at 200–210 lb./sq. in. as soon as the bath is clear melted and the carbon has reached any point below approximately 0.40% (above this level of carbon the reaction becomes violent). It is usual, depending on the condition of the bath, to feed either oxide or lime or both, just before the commencement of the oxygen blow.

The operation of the oxygen is so predictable that a sample is sent to the laboratory when the blow begins and the quantity of oxygen required is calculated from the carbon analysis. As soon as this amount has been delivered, the furnace is prepared for tapping. No other samples are required as far as carbon removal is concerned, and no further sample is sent to the laboratory until the tapping sample is taken.

During the oxygen blow, frequent bath temperatures are taken as guides to the oil flow required to supplement the heating effect of the oxygen. This may vary from zero to about two thirds of the normal oil flow. Approximately 100–150 gallons per charge is normally saved.

While it is too early to pass final judgement on the process, it does appear that if the blow is begun at 0.35% carbon, the average rate of removal of carbon is increased from 0.14%/hr. to 0.34%/hr. at an oxygen input rate of 35,460 cu. ft./hr. and to 0.42%/hr. for oxygen delivery averaging 46,500 cu. ft./hr. The time saved in a cast varies from 40 minutes if the blow is started at 0.1% carbon, to 95 minutes starting at 0.4% carbon, this being the carbon range within which oxygen is likely to be applied.

There is also an indication of a reduction in fettling time as a result of using oxygen, probably because of the shorter period during which the hearth refractories are exposed to the most severe conditions of temperature and iron oxide concentration in the slag. A reduction of about 20 minutes (from 75 to 55 on an average) appears to result.

There is a difference in the iron oxide concentration in the tapping slags of the oxygen blown casts (22.42%) compared with non-oxygen blown casts (23.9%). Other constituents are not significantly different but the CaO content of the slag in oxygen casts is 42.48% compared with the lower figure of 40.92% for the non-oxygen casts.

Roof lives do not appear to be greatly affected, but are certainly no shorter with oxygen casts than with non-oxygen casts. Present indications from the data available indicate lives of about one or two weeks more than average.

Dr. Kesterton stated that steel from the oxygen blown furnaces had been used for making tinplate at Trostre and a good report of its qualities had been obtained from a comparison of performance with non-oxygen blown steel.

#### Desiliconising Of Hot Metal

The conference also heard details of the desiliconisation of hot metal in the ladle by means of an oxygen lance from MR. C. A. REED of Skinningrove Iron Co., Ltd. In this process 30-ton transfer ladles are used, into which the 20 tons of hot metal from the inactive mixer is poured on to graded limetone and a little fluorspar. A further quantity of limestone is fed in by hand while the ladle is being filled. Oxygen is blown through a lance into each of two ladles at 250 cu. ft./min. for 20 minutes. The slag is then decanted and the metal taken to the open hearth furnace.

The work has been mainly experimental, but has shown that about half the initial silicon content can be removed in this way, with the following advantages to the steelmaker.

- (1) The metallurgical load on the open hearth furnace is reduced.
- (2) There is less wear on steel furnace banks and bottoms.
- (3) The temperature of the hot metal charged is 100 to 130° C. higher.
- (4) Limited quantities of steel scrap can be melted in the ladle.

The consumption of oxygen is 5,000 cu. ft. for each 20 tons of hot metal, i.e., 250 cu. ft./ton.

The members of the conference heard of other applications of oxygen in the United Kingdom, among them decarburisation at the Redbourn Works of Richard Thomas and Baldwins, Ltd. MR. S. R. ISAAC said that oxygen was lanced into the bath to take carbon down from, for example, 0.22% to 0.024% in about 70 minutes, using 12,000 cu. ft. of oxygen for 110 tons of steel. The saving in time was at least two hours, with additional

savings in fuel and refractories. By the use of oxygen they could get much lower carbon contents (0.025% or so) with a much lower Fe content in the slag—18% compared with 30% when refining was carried out by means of ore. Mr. Isaac thought that the use of a lance was probably more effective than impinging.

He thought that there were cheaper ways of improving combustion than using oxygen enrichment. Other contributors mentioned the advantages oxygen lancing offered for agitation of deep baths. It was thought that the mechanical effect of oxygen blowing was sometimes as important as the chemical effect, particularly in relation to increasing the lime content of the slag.

Mr. E. DAVIES of the Brymbo Steelworks suggested that approximately 1,200–1,400 cu. ft. of oxygen per ton, fed fast enough to hot metal before charging would desiliconise, considerably dephosphorise and partially decarburise the metal. He had carried out experiments to show that this was feasible. Another speaker suggested that refining by oxygen might radically affect the

design of open hearth furnace burners which might be made considerably smaller.

Dr. A. H. LECKIE of the Iron and Steel Board said there was strong evidence that it would be technically practicable to make steel from phosphoric iron by top blowing with oxygen. However, he was very doubtful whether this process would be more economic than the open hearth for converting phosphoric iron, even with tonnage oxygen at a cheap rate. The cost of electric power was quoted as a major item in the cost of oxygen. He asked whether it would be possible to reduce the cost of oxygen generation in a steel works by driving the plant direct, either from waste heat steam or from a blast furnace gas turbine, avoiding the use of purchased electricity.

On the question of costs and prices, the Chairman remarked that he understood continental makers had applied for an increase in the price of Thomas steel made with the help of oxygen to bring them into line with open hearth prices "because of the increased cost."

## BIRTHDAY HONOURS LIST—continued from page 2

J. W. WAGSTAFF, Cashier, Hadfields, Ltd.  
F. T. WEST, Principal, Southampton Technical College.  
W. O. WILLIAMS, Shift Manager, Treforest Chemical Company, Ltd.  
G. W. WILSON, Sales Director, Belmos Company, Ltd.

### B.E.M.

H. R. BATCHELOR, Foreman, Submarine Cables, Ltd.  
J. H. BENN, Table Knife Manager, John Blyde, Ltd.  
A. T. BROOK, Laboratory Worker, Grade "A," Armament Research Establishment, Woolwich.  
T. CALLAGHAN, Brickmaker, B. Whitaker & Sons, Ltd.  
W. J. CAMBRIDGE, Senior Overlooker, Royal Ordnance Factories, Woolwich.  
A. C. CLARKE, Brazier, Hammerman, Razor and Saw Piercer, Roberts & Belk, Ltd.  
A. CLARKSON, Blacksmith, Colvilles, Ltd.  
C. CUTTLER, Chief Saw Sharpener, J. Glikstein & Sons, Ltd.  
T. DICK, Foreman, Victor Products (Wallsend), Ltd.  
R. E. A. GATES, Toolmaker, Royal Ordnance Factory, Cardiff.  
A. H. GOGGIN, Research and Experimental Mechanic I, Royal Aircraft Establishment.  
A. HALL, Experimental Assistant, Aladdin Industries, Ltd.  
S. HENNEN, Foreman Blacksmith, Camper and Nicholsons, Ltd.  
G. HILL, Foreman, Bray Accessories, Ltd.  
R. G. HOWARD, Field Research Engineer, Davey, Paxman and Company, Ltd.  
F. ISHERWOOD, Toolroom Turner, Robert Stephenson and Hawthorns, Ltd.  
R. KEMSLEY, Chargehand, W. G. Bagnall, Ltd.  
H. G. KENDALL, Head Foreman Fitter, Vickers-Armstrongs, Ltd.  
G. J. LINDSAY, Foreman, Pressed Steel Company, Ltd.  
W. MCCALLUM, Draughtsman, Glenfield and Kennedy, Ltd.  
F. MANSELL, Coppersmith, Guy Motors, Ltd.  
E. MOODY, Foreman Fitter, Rose Brothers (Gainsborough), Ltd.  
G. W. MOORE, Pattern Shop Supervisor, Millspaugh, Ltd.  
W. F. MORTER, Research and Experimental Mechanic (Special), Department of Atomic Energy.

P. MOYES, Assistant Clerk of Works, J. & E. Hall, Ltd.  
P. O'KANE, Foreman, Ioco, Ltd.  
A. N. POWIS, Repair Manager, J. A. Mulhern and Company, Ltd.  
S. PUGH, Senior Foreman, Ambrose Shardlow and Company, Ltd.  
G. ROBINSON, Mechanic, National Physical Laboratory (Hampton, Middlesex).  
W. ROBINSON, Progressman (Technical), Admiralty Torpedo Experimental Establishment.  
W. RYAN, Foreman Joiner, Williams, Harvey and Company, Ltd.  
J. H. STEPHENS, Grade I Welder, Unit Superheater and Pipe Company, Ltd.  
C. WALKER, Foreman Electrician, Cabot Carbon, Ltd.  
T. WATSON, Instrument Maker, Radar Research Establishment.  
D. T. WILKINSON, Works Foreman, Meltham Silica Firebrick Company, Ltd.  
C. WILLIAMS, Foreman, Gloucester Railway Carriage and Wagon Company, Ltd.  
F. WOMERSLEY, Foreman, Maintenance Fitter, Steetley Magnesite Company.

## Turbo-Alternator for Steel Company of Wales

THE General Electric Co., Ltd., has received an order for a 2,500 kW. back-pressure geared turbo-alternator set for the Margam Works of the Steel Company of Wales, Ltd. The turbine is to operate under steam conditions of 600 lb./sq. in. pressure, 800° F. total temperature, and a back pressure of 165 lb./sq. in. The alternator will generate at 11 kV, 3-phase 50 cycles. Messrs. McLellan & Partners are the consultants for the Steel Company of Wales, Ltd.

## Additional H.B. Office in Glasgow

INCREASED business and the resulting expanding factory requirements have compelled Honeywell-Brown to establish an additional Glasgow office at 26, Blythswood Square, Glasgow. Mr. D. J. Venning has been appointed District Supervisor in charge of the office.

# The Creep Properties of 99.8% Purity Aluminium at 20-80°C. and at 250 and 450°C.\*

By J. McKeown,† D.Sc., M.I.Mech.E., F.I.M., R. Eborall,‡ M.A., and R. D. S. Lushey§

(Communication from the British Non-Ferrous Metals Research Association).

Prolonged creep tests at 20, 50, 80, 250 and 450°C. on 99.8% aluminium have provided data from which design stresses may be obtained. At the two highest temperatures the effect of grain size on the creep behaviour has been shown to be quite marked.

## Materials and Testing Conditions

THIS paper gives some data on the creep properties of annealed 99.8% purity aluminium sheet and plate. The materials used were commercially produced, and were fully softened by annealing before testing, as described below. Sheet 0.080 in. thick was used for the tests at 20-80°C. and rolled plate  $\frac{1}{4}$  in. thick for the tests at 250 and 450°C. In the annealed condition, the plate had a tensile strength of 4.6 tons/sq. in. and an elongation of 47% on 2 in. The compositions of the materials tested are given in Table I.

TABLE I.—ANALYSIS OF MATERIALS TESTED.

	Plate	Sheet
Iron %	0.11	0.07
Silicon %	0.07	0.07
Copper %	0.004	<0.01
Manganese %	Trace	0.004
Titanium %	Trace	0.003

The temperatures of test were maintained uniform to within 1°C. along the length of the specimen, and constant to within  $\pm 1^\circ\text{C}$ . The creep strain was measured to  $\pm 0.0025\%$ .

In starting a test at elevated temperature, the specimen and extensometer were placed in a cold furnace and the temperature was raised over a period of 4-6 hours to approximately the test value. After a further 20 hours, during which the temperature was stabilised at the test value, the load was applied as a single increment. An analogous procedure was adopted for tests at 20°C. Readings of the extensometer were taken before and after loading and subsequently at daily intervals. No attempt was made to determine the elastic component of the extension on loading, and the creep strain given in the tabulated data is the total strain (i.e., elastic + plastic).

The effect of grain size was investigated in the tests at 250 and 450°C. on the specimens from the  $\frac{1}{4}$  in. plate.

## Results of Tests

### Tests at 20-80°C.

As mentioned above, these tests were carried out on specimens cut from the sheet having a thickness of 0.080 in. The specimens were annealed at 350°C. before they were tested. The results obtained are given in Table II, from which it may be noted that creep was still occurring at a measurable rate after 5,000 hours at

TABLE II.—CREEP TESTS AT 20, 50 AND 80°C.

Temp. of Test °C.	Stress lb./sq. in.	Extension % after						Creep Rate* strain/hr.	Duration of Test hr.
		100 hr.	500 hr.	1,000 hr.	1,500 hr.	2,000 hr.	5,000 hr.		
20	2,000	0.025	0.032	0.036	0.039	0.040	0.040	0	6,000
	2,500	0.082	0.090	0.092	0.092	0.092	0.092	0	7,000
	3,000	0.235	0.245	0.250	0.255	0.257	0.265	$<0.5 \times 10^{-7}$	7,000
	3,500	0.370	0.380	0.390	0.395	0.400	0.415	$0.5 \times 10^{-7}$	7,000
	4,000	0.940	1.145	1.280	1.365	1.435	1.700	$4.5 \times 10^{-7}$	7,000
50	1,600	0.045	0.052	0.057	0.064	0.070	0.080	$<0.5 \times 10^{-7}$	5,000
	1,900	0.052	0.075	0.085	0.090	0.095	0.110	$0.5 \times 10^{-7}$	5,000
	2,200	0.090	0.107	0.127	0.180	0.187	0.260	$1.0 \times 10^{-7}$	5,000†
	2,500	0.213	0.280	0.324	0.345	0.355	0.415	$2.0 \times 10^{-7}$	5,000
80	600	0.020	0.023	0.025	0.030	0.032	0.038	$<0.5 \times 10^{-7}$	5,000
	800	0.022	0.027	0.035	0.040	0.043	0.055	$0.5 \times 10^{-7}$	5,000
	1,000	0.025	0.035	0.045	0.055	0.060	0.070	$0.5 \times 10^{-7}$	5,000
	1,200	0.030	0.047	0.065	0.070	0.082	0.110	$1.0 \times 10^{-7}$	5,000

\* Rate at end of testing time.

† Discontinuities in the creep curve.

a stress of 3,000 lb./sq. in. at 20°C., 1,600 lb./sq. in. at 50°C., and 600 lb./sq. in. at 80°C.

### Tests at 250 and 450°C.

These tests were carried out on specimens taken from  $\frac{1}{4}$  in. plate which was given the following treatments to obtain two different grain sizes.

- Medium Grain Size.** Half-hard plate was annealed for 24 hours at 450°C. and air cooled. The average grain diameter was 0.09 mm.
- Coarse Grain Size.** Material produced as in (a) was stretched 5% and annealed for 6 hours at 600°C. The average grain diameter was 1.4 mm.

To test the reproducibility of creep behaviour, three specimens were chosen at random from the medium grain size material, and were each tested at 450°C. at a stress of 50 lb./sq. in. The strains at different times are given in Table III, and indicate a satisfactory degree of reproducibility in the material.

The results of the creep tests are given in Table IV, from which it will be seen that at both temperatures of test the coarse-grained materials were much the more creep resistant. For both grain sizes the effect of temperature on the load carrying capacity of the materials was equally marked. At 450°C. the medium-

TABLE III.—REPRODUCIBILITY TESTS AT 450°C. AND 50 LB./SQ. IN.

Specimen No.	Extension % after					
	200 hr.	500 hr.	1,000 hr.	1,500 hr.	2,000 hr.	2,370 hr.
1	0.20	0.33	0.50	0.68	0.88	1.02
2	0.22	0.35	0.52	0.68	0.88	1.02
3	0.24	0.37	0.54	0.70	0.92	1.08

\* B.N.F.M.R.A. Report R.R.A., 1052P, based on R.R.A. 878 and 880.

† Head of Mechanical Testing Section, B.N.F.M.R.A.

‡ Head of General Metallurgy Section, B.N.F.M.R.A.

§ Research Assistant, B.N.F.M.R.A.

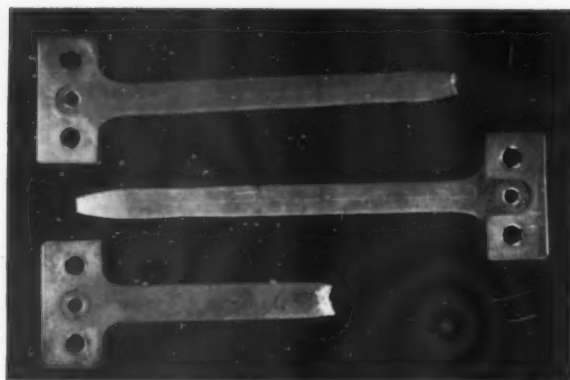


Fig. 1.—Fractured specimens: top—450° C. and 200 lb./sq. in., medium grain; middle—250° C. and 1,000 lb./sq. in., medium grain; bottom—450° C. and 400 lb./sq. in., coarse grain.

grained material showed creep continuing after 3,000 hours at a stress as low as 25 lb./sq. in. The coarse-grained material, on the other hand, showed no measurable creep at a stress of 50 lb./sq. in., except during the first 500 hours. At 250° C. continuous creep was observed over the whole 3,000 hours testing time in the medium-grained material at a stress of 200 lb./sq. in., whereas the coarse-grained material showed no measurable continuous creep at a stress as high as 1,000 lb./sq. in.

Two specimens of the medium-grained material, one tested at 450° C. and one at 250° C., broke during the testing period and both showed a satisfactory amount of general extension. Only one specimen of the coarse-grained material broke, and this was in a test at 450° C. under a stress of 400 lb./sq. in. This specimen showed no general extension, and only a small amount of local

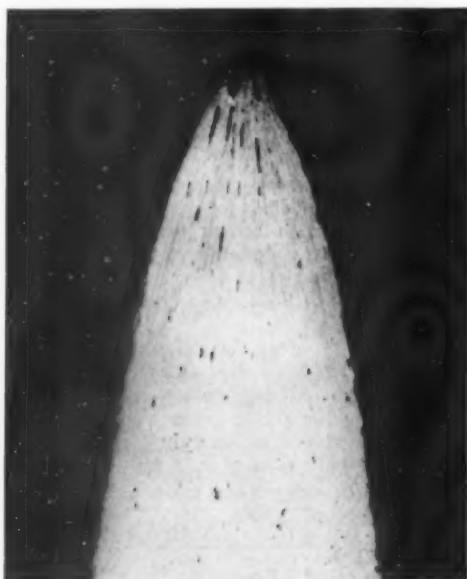


Fig. 2.—Medium-grained specimen tested at 250° C. and 1,000 lb./sq. in.

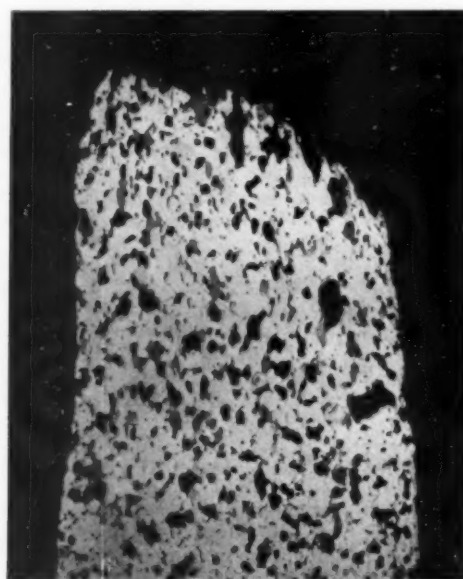


Fig. 3.—Medium-grained specimen tested at 450° C. and 200 lb./sq. in.

TABLE IV.—CREEP TESTS AT 250 AND 450° C.

Grain Size	Temp. of Test ° C.	Stress lb./sq. in.	Extension % after					Duration of Test hr.	Final Extension %
			200 hr.	500 hr.	1,000 hr.	2,000 hr.	3,000 hr.		
Medium 0.09 mm. dia.	250	200	0.02	0.02	0.025	0.03	0.04	3,200	0.04
		400	0.06	0.09	0.14	0.23	—	3,200	0.35
		600	0.35	0.85	1.69	3.04	—	2,200	3.3
		1,000	11.5	34	—	—	—	572	63 F*
	450	25	0.08	0.13	0.16	0.18	0.20	3,200	0.2
		50	0.32	0.57	0.89	1.62	2.34	3,200	2.7
		100	2.5	4.8	8.6	17.0	42.8	3,200	49
		200	12.4	—	—	—	—	250	42 F†
	250	400	0.01	0.01	0.01	—	—	1,600	0.01
		600	0.01	0.01	0.01	0.01	0.01	3,000	0.01
		1,000	0.04	0.04	0.04	0.04	0.04	3,200	0.04
		1,200	0.06	0.07	0.08	—	—	1,300	0.08
		1,600	0.38	0.40	—	—	—	500	0.4
		2,000	1.05	1.10	—	—	—	500	1.1
Coarse 1.4 mm dia.	450	50	0.005	0.01	0.01	0.01	—	2,400	0.012
		100	0.02	0.02	0.02	0.025	0.030	3,200	0.030
		200	0.01	0.01	0.01	0.015	0.020	3,200	0.023
		400	0.00	0.36	—	—	—	600	3.7 F‡

F Fractured.

\* General extension 45%.

† General extension 26%.

‡ General extension nil.

extension. Photographs of these broken specimens are shown in Fig. 1. The coarse-grained specimen broken at 450° C. showed a short, broad fracture, whilst the medium-grained specimen broken at 250° C. showed a chisel-edge fracture.

Detailed examination showed that in some of the specimens, especially those tested at the higher temperature, much intercrystalline movement had occurred, there being marked steps from grain to grain. There were marked intercrystalline fissures near the fracture of the coarse-grained specimen which broke at a stress of 400 lb./sq. in. at 450° C.

Examination of a microsection showed that lateral separation of the crystals had occurred in the neck of the medium-grained specimen broken at 250° C. (Fig. 2). That broken at 450° C., which had a broader fracture,



Fig. 4.—Medium-grained specimen tested at 450° C. and 100 lb./sq. in. Unbroken—49% extension.

showed marked transverse intercrystalline cracking, and near the fracture this had opened out into large pores (Fig. 3). The process is seen at an earlier stage in Fig. 4. The coarse-grained specimen, Fig. 5, showed marked intercrystalline cracking just behind the fracture, but not much elsewhere.

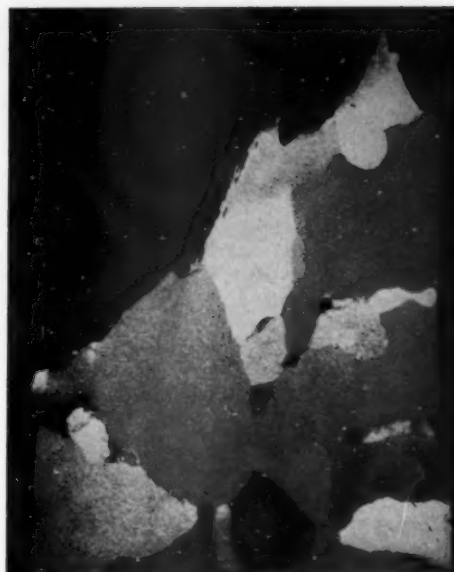


Fig. 5.—Coarse-grained specimen tested at 450° C. and 400 lb./sq. in.

### Conclusions

Prolonged creep tests at 20, 50, 80, 250 and 450° C. on 99.8% aluminium have provided data from which design stresses may be obtained. At the two highest temperatures the effect of grain size on the creep behaviour has been shown to be quite marked.

## New and Revised British Standards

### METHODS FOR THE ANALYSIS OF IRON AND STEEL

#### PART 13: CHROMIUM IN IRON AND STEEL

#### PART 30: COBALT IN IRON AND STEEL

#### PART 31: SILICA IN BLASTFURNACE SLAG (B.S. 1121, PARTS 13, 30 AND 31: 1954)

PRICE 2s. EACH PART

PART 13 is a revision of the 1949 edition, and its scope includes the range of chromium previously dealt with in Part 8, which is now withdrawn. The principle of the method is solution in phosphoric-sulphuric acid, oxidation with ammonium persulphate in the presence of silver nitrate which acts as a catalyst, reduction by hydrochloric acid of the permanganic acid and titration of the oxidised chromium with standard ferrous ammonium sulphate and potassium permanganate.

Part 30 is a new section covering a range of up to 12% cobalt, and involves the addition of nitroso-R-salt to a neutral or buffer, solution containing cobalt. This produces a reddish-brown colour proportionate to the amount of cobalt present. Interfering complexes of other metals are destroyed by the addition of nitric acid followed by a short period of standing. The method has given satisfactory results on a wide variety of alloy steels.

Part 31 is also a new section and covers the range of silica contents found in blastfurnace slags. The method is to decompose the sample by fusion with sodium carbonate, dissolve the fused product in perchloric acid and dehydrate the silica by fuming. Insoluble silica is

removed by filtration and the residual silica in the filtrate is recovered by a second fuming treatment. The combined silica precipitates are ignited and weighed, and silica is determined by the loss in weight on treatment with hydrofluoric acid.

### FERROUS PIPES AND PIPING INSTALLATIONS FOR AND IN CONNECTION WITH LAND BOILERS (B.S.806: 1954).

PRICE 10s. 6d.

This British Standard supersedes the 1942 edition. It applies to the design and construction of the ferrous pipework connecting a land steam boiler to engine, turbine or industrial plant, and all auxiliary pipework in connection therewith, together with the pipes and pipe fittings forming parts of such installations for: (a) pipes of any bore where the pressure exceeds 50 lb./sq. in.; (b) pipes over 10 in. bore for steam at pressures up to and including 50 lb./sq. in. This standard does not apply to the use of carbon steel where the temperature exceeds 900° F., nor to the use of alloy steel where the temperature exceeds 975° F.

The scope of this standard has been extended to provide for developments which have taken place in pipe-work installation practice, notably in the use of alloy steels.

Copies of these standards can be obtained from Sales Branch, British Standards House, 2, Park Street, London, W.1.

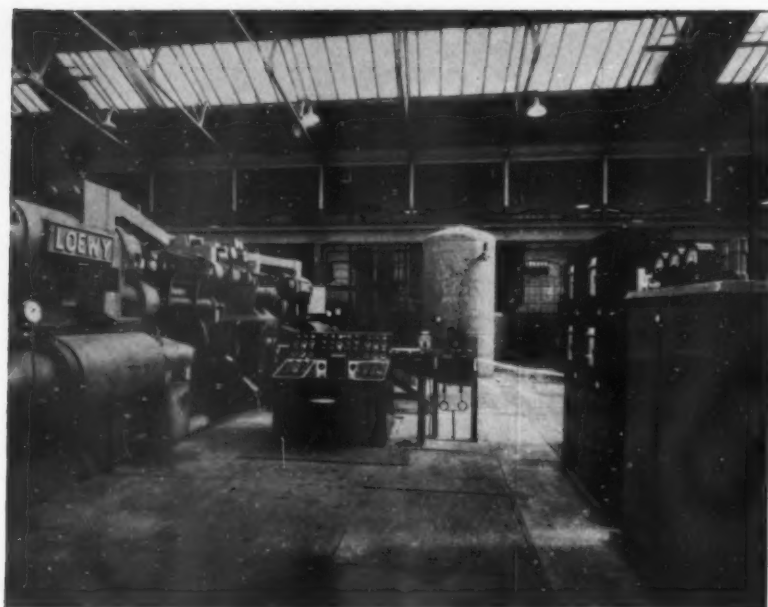


Fig. 1.—View of front of press and control desk.

# Aluminium Cable Sheathing Press

## Direct Extrusion on to Cable Possible on New B.I.C.C. Plant at Prescott

**A**N advance of considerable importance has been made at the Prescott works of British Insulated Callender's Cables, Ltd., where the installation of a new press makes possible the continuous extrusion of aluminium for power cable sheathing to any desired length. The press has been developed in collaboration with the Loewy Engineering Co., Ltd.

The characteristics of aluminium sheaths for power cables are well known, and in Great Britain there already exists considerable experience of cables with sheaths produced by the tube-sinking method, in which an over-size tube is threaded over the cable and worked down to a close fit. Interest in the direct extrusion of aluminium sheaths on to power cables goes back a quarter of a century, during which period numerous efforts have been made to develop a satisfactory process, but only of late have there been prospects of practical success.

After close study of the problems involved, and after much preliminary experimental work, British Insulated Callender's Cables, Ltd. concluded, a few years ago, that the following conditions must be satisfied if the extrusion of aluminium sheaths is to take its place as a normal production process:

- (1) The method should be suitable for use with commercial grades of aluminium.
- (2) The technique should be based on the use of solid billets.
- (3) The extrusion temperature should be as low as possible, preferably not exceeding 300° C.
- (4) The process should be capable of producing sheathed cable in long continuous lengths.
- (5) The welds between successive billets should be satisfactory from all points of view.
- (6) The extrusion press should be capable of being charged rapidly to prevent overheating of the cable whilst it is stationary in the press.

- (7) Deformation and undesirable metallurgical features should be avoided at "stop-marks"—i.e. that section of the sheath which is within the die when the cable is stationary during recharging.

As no existing press combining all these features was available, B.I.C.C. and the Loewy Company co-operated in the development of an extrusion press which could provide the facilities required. The result of this collaboration is the Alsheath press made by the Loewy Engineering Co., Ltd., and installed at Prescott. This press is believed to be unique. It is hydraulically operated, with two horizontally-opposed cylinders, each 45 in. in diameter, operating at 4,280 lb./sq. in. pressure, and each giving a nominal thrust of 3,000 tons. Twin billets are extruded through a common core and die to give sheaths ranging from 1.4 in. to 3.5 in. in diameter.

The billets of commercially pure aluminium are heated in a G.W.B. electric furnace which accommodates 96 billets arranged in 6 rows of 16. The furnace is of the pusher type, and by the time the billets reach the discharge end they have been heated uniformly to 285° C. When extrusion of a pair of billets is almost complete, two further billets are discharged from the furnace, one on to each of the two roller conveyors shown in the layout diagram (Fig. 2). Three rows of billets feed each conveyor, the end billets from corresponding rows of each group forming pairs. From the conveyors the billets are discharged on to loading platforms, one on each side of the extrusion chamber. During the raising of these platforms the billets are turned through 90° so that they are ready for pushing into the extrusion containers by the simultaneous operation of the two horizontally-opposed hydraulic rams. As soon as the openings in the extrusion chamber are closed by the entering billets, a 30-in. vacuum is applied to remove all the air between the new billets and the ends of the previous billets. This is a most important stage in the operation of the press,

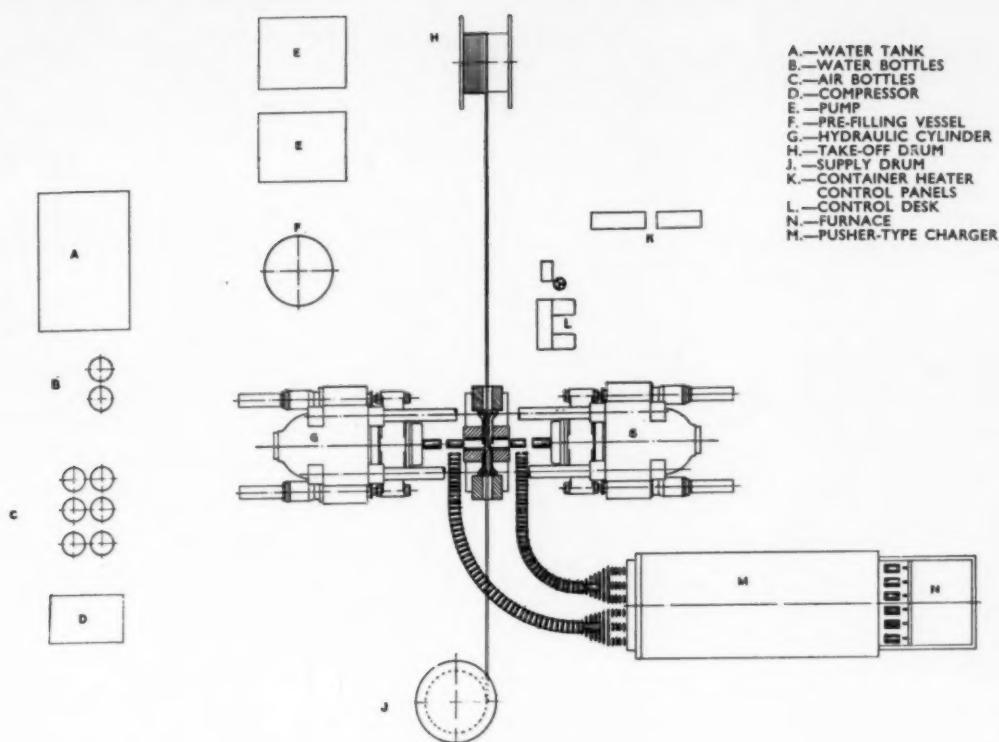


Fig. 2.—Simplified plan of equipment.

as without it the quality of the extruded sheath would not be satisfactory.

Each of the cylindrical containers of the extrusion tools is electrically heated, and the temperature, which is measured at 6 points on each container is thermostatically controlled.

The cable is fed from a supply drum through the core and die, where the sheath is extruded on to it, and on to a take-off drum. One of the difficulties of the process is the avoidance of damage to the insulation due to the elevated temperature used. It is for this reason that

the temperature has to be kept as low as possible, and before entering the extrusion chamber the surface of the cable is oiled to provide a heat insulating film.

It will be realised from the description of the process given above that the cable remains stationary for a period whilst billet recharging takes place. The time involved is about a quarter of a minute, and the flow of cooling water round the extrusion dies is temporarily augmented to prevent overheating. The extrusion tools are so arranged that they maintain their relative positions with a fixed gap, independent of elastic deformation due

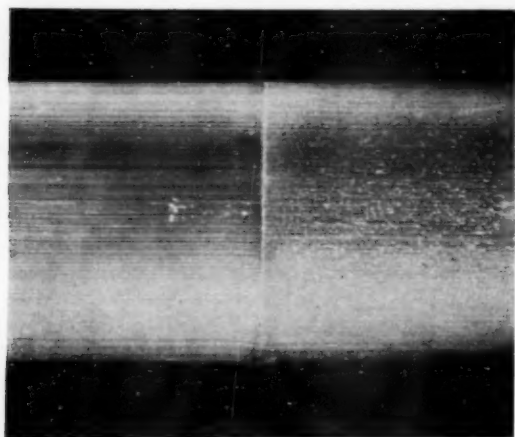


Fig. 3.—Photograph showing "stop-mark" position on as-extruded sheath.

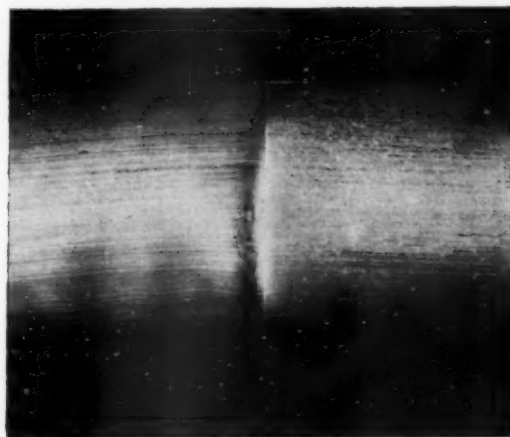


Fig. 4.—"Stop-mark" after subjecting to bend test involving 4 bends over mandrel of 24 times the tube diameter.

to temperature variations, so that the extruded sheet is free from weakness at "stop-marks."

All major movements of the press are controlled by servo-operated valves from a central control desk which provides for fully-automatic control or individual control, as desired.

Trials to date indicate that all the initial objectives are being met, and that the press is approaching the stage when it will take its place as a routine tool in cable manufacture. Enough cable has been sheathed to show that the "stop-marks" are satisfactory from the dimensional and metallurgical aspects; they comply with the appropriate bend test requirements and they can with-

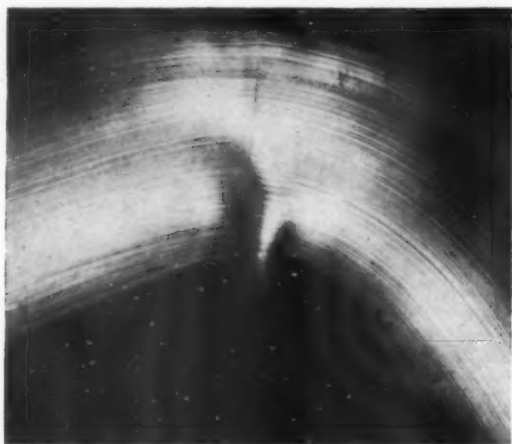


Fig. 5.—The excellent mechanical strength of the metal is shown in this photograph of the "stop-mark" during test to full destruction.

stand the high hoop stress. Figs. 3, 4 and 5 show specimens before and after bend tests.

The welds formed between successive billets (as distinct from stop marks) are not discernible in the extruded sheath, and the top and bottom welds inherent in any right-angle extrusion resemble those formed in the conventional lead press. (See Fig. 6).

With aluminium of 99.8% purity, and extrusion temperatures of 280° C., the extruded sheaths are in the lightly annealed condition. The tensile strength is

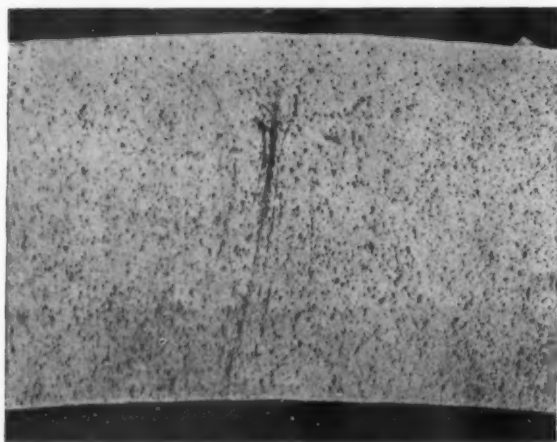


Fig. 6.—Photomicrograph of transverse section of tube, showing seam features at top position.  $\times 22$

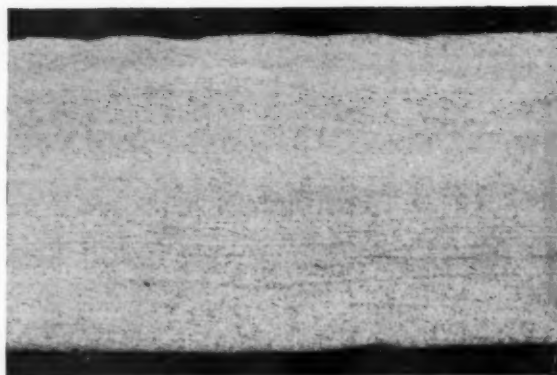


Fig. 7.—Photomicrograph of longitudinal section of tube, taken through "stop-mark" (confirming absence of grain growth.  $\times 22$

5.0 to 6.0 tons/sq. in., and the elongation on a length of 2 in. in the longitudinal direction of the sheath is 30% to 50%, depending on diameter and thickness. The grain size is fine at all parts of the sheath including "stop-marks" (Figs. 7 and 8). These properties ensure that the springiness associated with cold working is largely eliminated.

Much remains to be done in equipping the press with the tools required for a comprehensive range of cable



Fig. 8.—Photomicrograph of longitudinal section of tube, showing fine grain.  $\times 200$

size and in proving its performance over that range. Sufficient has been done, however, to indicate that the procedure described offers a practical solution of the problems which have engaged the attention of cable makers and of press designers for many years.

### M.V. Heating and Welding Merger

THE heating and welding activities of Metropolitan-Vickers Electrical Co., Ltd., have been further co-ordinated. The Engineering Sections dealing with all forms of H.F. heating (induction furnaces, dielectric heating, etc.), as well as resistance heating using sheathed tubular elements, have been combined with the Welding Engineering Department, under its Chief Engineer, Mr. C. F. Saunders.

# Aluminium Sheet and Strip Production

## New T.I. Aluminium Plant in Operation at Resolven

*On a site previously partly developed by the South Wales Aluminium Co., Ltd. for the reduction of aluminium from alumina, T.I. Aluminium Ltd., have now put into operation a semi-continuous rolling mill for the production of aluminium alloy sheet and strip in matt mill-finish and other qualities. A brief description of the mill and associated plant is presented here.*

RATHER more than twenty years ago Tube Investments, Ltd., entered the aluminium fabricating industry with the production of tubing to meet the heavy demands of the aircraft industry. This was quickly followed by the production of extruded sections, and this branch of T.I. Aluminium's activities is now centred at Redditch, in works erected for the Ministry of Aircraft Production in 1940, and extended in 1942. In 1936 T.I. laid down an up-to-date rolling mill at Oldbury, to produce sheet and strip in the high strength aluminium alloys, and immediately after the war this mill was fully occupied in the production of material for the aluminium house programme.

In 1946, a detailed survey was made of likely future developments for aluminium and allied products which could conveniently be divided into three main categories:

- (1) Heat-treated sheet and strip in high and medium strength alloys for the aircraft industry, road and rail transport and certain structural applications, representing some 20% of the total.
- (2) Bright or lustre-finish sheet in pure aluminium and low strength alloys to meet specific needs; such material has hitherto had almost universal application.
- (3) Mass produced standard sheet and coiled strip in pure aluminium and in low and medium non-heat-treated alloys, to close dimensional tolerances, with good deep-drawing and forming properties, and having a regular clean surface finish, represents the greatest potential demand.

At the same time the latest rolling techniques both in the U.S.A. and Canada were studied and, as a result, a new rolling mill which is now in full-scale production has been erected in South Wales. The product of this semi-continuous mill is matt mill-finish sheet and coiled strip, and falls into the last of the three categories referred to above. As a result of the planned techniques used in its production, it is claimed that this product sets new standards for (a) uniform mechanical properties; (b) dimensional accuracy; (c) cleanliness of surface; (d) improved lubricant adhesion for press work; (e) reduced liability to surface damage during fabrication; and (f) improved adhesion of paint finishes.

### Site and Buildings

The site chosen for the new rolling mill at Resolven, near Neath, had previously been partly developed by the South Wales Aluminium Co., Ltd., for the reduction of aluminium from alumina, for which purpose buildings and services had been provided on a portion of the site, leaving ample land for the rolling mill project. The site covers 36 acres and lies to the north of the main road to

Neath, and additional land on the south side of this road is available for future development.

The original buildings covered a floor area of some 200,000 sq. ft., and by expansion and adaptation certain of them have been incorporated into the new development plan. Two main shops, originally housing reduction furnaces, have been cleared and overhead cranes installed, and these now form in integral part of the new mill, lying at right angles across one end of the main new bays. The original foundry building has been considerably extended, as has also the laboratory. The new rolling mill buildings cover a floor area of 272,000 sq. ft., with three main bays, each 840 ft. long and 95 ft. span, the whole area being uninterrupted except for two rows of columns between the bays at 33 ft. centres. The height to the underside of the main roof girders is 38 ft. 6 in. The roof is of north light form running across the bays, with continuous glazing incorporating aluminium glazing bars. The cover of the other slope is Ruberoid decking. There are also two stretches of aluminium-framed windows on the vertical sides with opening lights. Gantries in each bay carry a total of six 25-ton cranes made by the Clyde Crane and Engineering Co., Ltd. Along the south side of the main bays runs a brick-built lean-to motor house, some 400 ft. long, with aluminium roof trusses and clad with aluminium roof decking. A brick-built soluble-oil cooling tower is also incorporated into the design. On the north side is situated a works administration office block in two storeys, and a smaller motor house catering for the cold rolling mills. At right angles to the northernmost main mill bay and at one end is the inspection and despatch bay 222 ft. by 90 ft. span. Continuous roof and side wall glazing is provided and the remainder of the roof is again covered with Ruberoid decking. Crane gantries are provided to carry a 10-ton crane with the gantry constructed in aluminium by the Clyde Crane and Engineering Co., Ltd.

Still in the course of erection is a further building, in which will be housed both new and existing two-high sheet rolling mills and strip mills from Oldbury equipped with individual drives. This is a pitched roof, welded-box portal structure 400 ft. long by 70 ft. span, with a height to the eaves of 28 ft. There are four rows of continuous aluminium roof glazing and full height aluminium windows, and the roof is covered with aluminium decking by Ruberoid. All gutters, downpipes and other rainwater goods are also in aluminium. The whole building is constructed in such a way that there are no lodging places for dust, which might result in impaired surface finish of the sheet.

An additional portal framed bay running across one end of the shop will house a modern heat-treatment department, and there will be full ancillary equipment



**Semi-continuous casting of aluminium alloy slabs.**

for the flattening and shearing of sheet up to 6 ft. in width and 20 ft. long. Besides sheet in the heat-treatable alloys and lustre-finish, tread plate, pattern sheet, and many other special qualities will be processed in this department.

### **Slab Production**

Ingot metal from Canada is delivered by rail from Swansea Docks to the material stock yard, from which it is drawn as required for use in the foundry, where, along with alloying additions, it is melted down to form the required alloys. The main melting equipment comprises six reverberatory gas-fired furnaces made by Gibbons Bros., Ltd. These furnaces are arranged in pairs and have integral holding baths to which the molten metal from the melting hearth is transferred by gravity. The total capacity of each furnace is 20 tons, but in the case of two pairs the melting hearth and holding bath hold 13 tons and 7 tons, respectively, whilst in the latest pair the capacities of the melting hearth and holding bath are both 10 tons.

Situated between each pair of furnaces is a semi-continuous casting machine to the Company's own design, in which the control of the ram drop is by means of a Weatherly infinitely variable hydraulic pump unit. The molten metal runs directly to the head of the casting machine from the furnace holding bath by gravity, via launders in which are incorporated automatic flow valves. Depending on the size of slab being cast is the number cast at one drop, the larger slabs with a cross section of 50 in. by 10 in. being cast in pairs with a total weight of 6 tons.

The foundry is also equipped with a number of smaller auxiliary oil-fired furnaces, and, in addition to the slabs for the strip-rolling mill, extrusion billets for use at the Redditch Works are cast. Prior to casting, and while the metal is in the holding bath, samples are analysed to ensure that the composition is

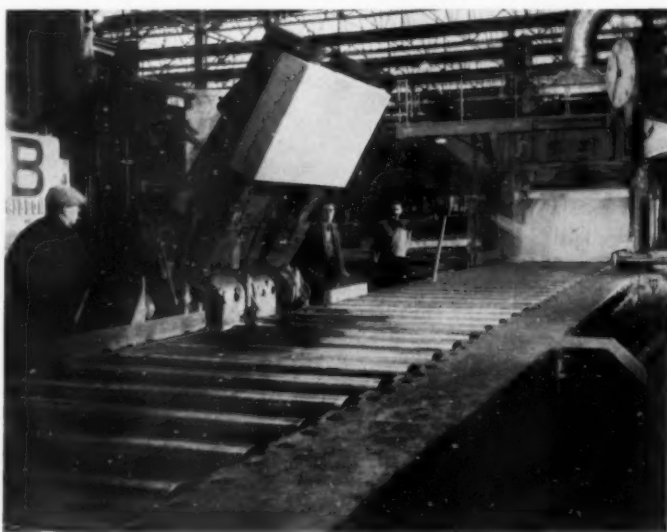
correct. This analysis is carried out electronically by a Quantometer, an automatic recording spectrograph which, in a matter of a few minutes, can determine the percentage of no less than 13 different elements which may be contained in the metal. When the analysis is completed, signals are exchanged between Quantometer control and the furnace overseer and, subject to minor adjustments which rarely have to be made, pouring is then commenced.

After transfer to the slab preparation shop, the slabs are cut into lengths on Noble and Lund fluid-feed sawing machines having blades of 38 in. diameter. They are then moved to the Holroyd vertical spindle scalping machines, whose 51-in. dynamically balanced cutter heads have a peripheral speed of 6,000 ft./min. These machines are arranged in pairs with turnover tables between them, so that first one and then the other side of the slab is scalped. After cutting and scalping to standard sizes, the slabs are held in stock against rolling requisitions. As required by the rolling programme, the slabs are taken by crane and lowered on to a conveyor which transfers them to the rear of the preheating furnace.

### **Breaking Down Mill**

Overhead hoists up-end the slabs and place them on chairs for traverse through the two double-chamber preheating furnaces supplied by Gibbons Bros., Ltd. The internal dimensions of the heating chamber are 9 ft. wide by 5 ft. 3 in. high by 63 ft. long, and heating is effected by gas-fired radiant tubes. Uniformity of temperature is achieved by forced air circulation which is used in nine zones, individually controlled by Kent equipment. The heated slabs are mechanically extracted from the furnace and lowered on to a live roller table feeding the hot mill.

The hot mill line processes cast slabs 10 in. thick, weighing up to 3,500 lb., into continuous coil of a minimum



**Reheated slab being placed on the breaking-down mill run-up table.**

thickness of 0.062 in. This is standard stock for further processing by cold rolling, but it can also be supplied for subsequent manufacture into a wide range of products. Its physical properties range from soft to hard temper in pure aluminium and the non-heat-treatable alloys, and it is very suitable for pressing or roll forming. The surface is clean and free from blemish, and satisfactory for a number of applications. Such material can be supplied in coil up to 4 ft. wide, or as flat sheet of similar width up to 20 ft. long.

Another product of the hot mill line is sheared blank in the heat-treatable alloys for subsequent cold rolling, and due to the power of this line compared with the more orthodox hot mills, considerably less cold rolling is necessary than is the general practice, resulting in a product having less directionality.

The first mill in the hot line is a 2-high reversing mill by Brightside Foundry and Engineering Co., Ltd., which has rolls of 35 in. diameter by 80 in. long, running in fabric bearings, and has a rolling speed of up to 475 ft./min. The drive is by a 1,800 h.p., 40/52 r.p.m., D.C. reversing motor with a maximum operating horse-power of 4,950, supplied from a motor generator set which is in turn driven by a 2,500 h.p., 6,600 volt, induction motor and 65,000 h.p./sec. flywheel, by Metropolitan-Vickers Electrical Co., Ltd. For the first few passes through this mill, the slab is turned broadside on to the rolls, so that its width can be adjusted to that necessary for the production of the required width of strip. The slab is then turned through 90° and rolled in the longitudinal direction until its thickness is reduced to  $\frac{1}{4}$  in.—i.e. one-fortieth of the original thickness. This involves a corresponding increase in length which must be accommodated on the run-out table. The roller feed table for the breaking down mill is 138 ft. long, and the total length of the run-out table is 500 ft., which



Run-out table with tandem hot mill in background.

is divided into two individually controlled sections.

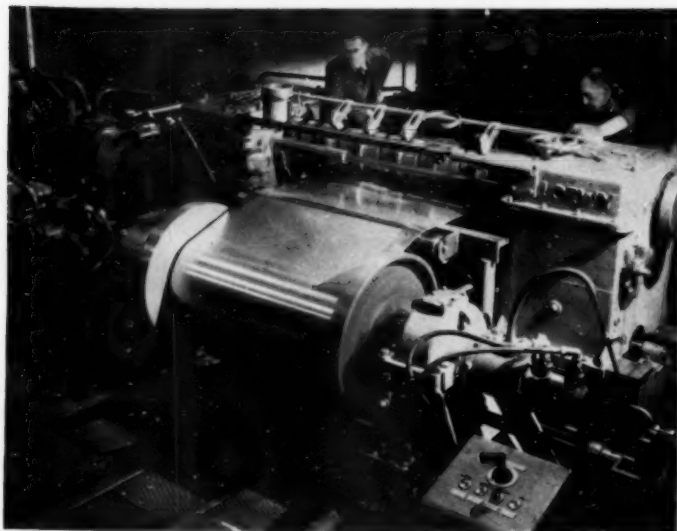
Situated between the breaking down mill and the tandem mills, in the following order, are the Head-Wrightson 1 in. by 98 in. up-cut shear, the Loewy edge trimmer having 21 in. diameter cutters adjustable to 70 in. width, and a  $\frac{3}{8}$  in. by 54 in. up-cut shear, also by Head-Wrightson Machine Co., Ltd. Four pairs of side manipulators are provided, one on each side of the breaking down mill, one pair at the edge trimmer, and one adjacent to the  $\frac{3}{8}$  in. up-cut shear. These and all live roller tables were supplied by the Brightside Foundry and Engineering Co., Ltd.

#### Tandem Hot Mill

After end trimming on the  $\frac{3}{8}$  in. up-cut shear, the material enters the 3-stand, 4-high hot tandem mill at 350°C. These mills by W. H. A. Robertson & Co., Ltd.,

have 17 in. diameter by 60 in. long work rolls, with 42 in. diameter backing rolls, all running in roller bearings. Each stand is driven by a 1,500 h.p. D.C. motor, giving rolling speeds of up to 200 ft./min., on the first stand, 420 ft./min. on the second stand, and 500 ft./min. on the third stand. Two motor generator sets supply the D.C. motors, one driven by a 3,200 kVA synchronous motor, and the other by a 1,500 kVA synchronous motor, both being wound for 6,600 volts and designed to run on unity power factor. Control of strip tension and interstand, speed is automatically maintained by special exciter sets; the whole drive again being by Metropolitan Vickers Electrical Co., Ltd.

Material up to  $\frac{1}{8}$  in. thick in coils of 34 in. diameter by 50 in. wide, can be taken on the drum coiler at the exit end of the mill (thicker material is coiled on a three-roll coiler). The coils are stripped off the drum and run by gravity conveyor to a weighing machine, and thence to a cooling conveyor, in readiness for further processing.



Edge trimming and slitting machine.



Charging one of the three electric annealing furnaces.

### Annealing and Cold Rolling

At this point there is a natural break in production flow for two reasons. Firstly, coiled products produced in the tandem mills have a fair surface finish and are even suitable for immediate use, subject to final trimming, in applications where surface finish is of less importance and semi-hard temper will suffice. Secondly, coils from the tandem mills are held as standard intermediate stock for the production of mill finish coil and sheet by cold rolling.

Prior to cold rolling, the coils from the tandem mill are transferred to three electrically-heated annealing furnaces with up-ender, loading crane and furnace charger, by the Stordy Engineering Co., Ltd. External heaters are employed, and air is continuously circulated at high speed between the heaters and the furnace chamber. The heater unit for each furnace is sub-divided to give 140, 215 and 280 kW, or any combination of these readings. The furnaces are designed to anneal two tons of coil material per hour.

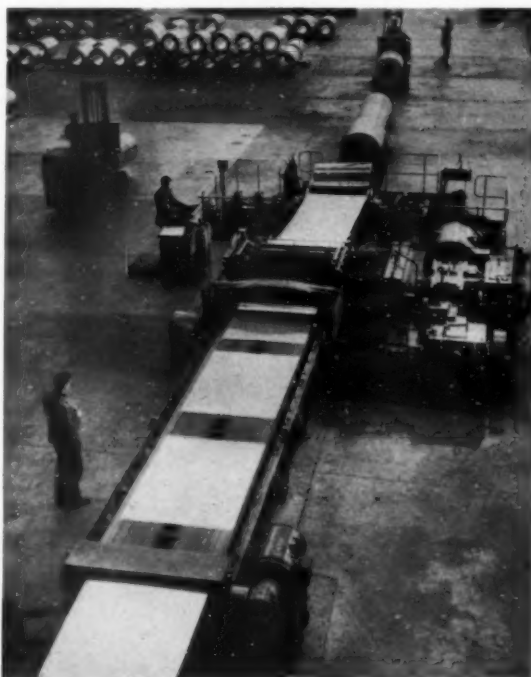
After edge trimming and slitting, where required, the coils are cold rolled in 17 in. by 42 in. by 60 in., 4-high non-reversing strip mills equipped with ingoing conveyors and roller bridles and belt wrappers and drum coilers on the outgoing side. The first mill, which is now in operation, was supplied by W. H. A. Robertson & Co., Ltd., who are also responsible for all strip-rolling auxiliary equipment on the second mill, the mill itself being supplied by Davy and United Engineering Co., Ltd. The maximum rolling speed is 1,000 ft./min., a typical final reduction for thin material on 3,000 lb. coils, 50 in. wide, being from 0.030 to 0.014 in. Both mills are driven by 1,500 h.p., D.C. motors, deriving current from two 7,000 kW generators by English Electric Co., Ltd. The generator motor drive is a 2,200 h.p., 6,600 volt, 0.8 leading power factor synchronous machine, and is direct coupled to the two generators above and the reel booster and drag generator. In addition to these finishing mills is installed a special hydraulically controlled 2-high, non-reversing, 18 in. by 48 in., Robertson temper rolling mill, designed to reduce strip

from 0.040 in. to 0.012 in. In this mill certain special products are produced, such as foil stock, of which large quantities are used annually for the production of what is commonly known as "silver paper." This mill, which incorporates several interesting features, including hydraulically controlled back tension equipment, has a 500 h.p. D.C. main motor receiving its supply from a 405 kW generator driven by a 650 h.p. synchronous, 1.0 power factor motor.

### Finishing Lines

Coils from the cold-rolling mills are transferred to an edge trimming and slitting machine supplied by the Loewy Engineering Co., Ltd., with re-coiling train operating up to 500 ft./min. The machine is driven by Vickers V.S.G. hydraulic pumps and motors which, with special control, maintain a tension on the strip of 5,000 lb. After trimming or slitting, the coils are ready for despatch to those industries where equipment is available to handle them in their own production processes, and when this is the case very considerable economies can

naturally be effected. This usage is slowly growing in this country, but still lags considerably behind that of the U.S.A., where the acceptance of coiled sheet is more common practice. However, flattened sheet is still in great demand, and ample provision has been made to produce it in bulk quantities from coil. Two Halden lines supplied by W. H. A. Robertson & Co., Ltd., have been installed for continuous levelling and shearing of sheet from coiled material, one up to 48 in. wide and a second up to 54 in. wide, and from 30 in. to 20 ft. long.



Levelling and shearing line.

The speed of operation of both lines is up to 300 ft./min., and belt conveyors transfer cut and flattened sheet to a stacking frame. Installed in line with the 54-in. machine is a universal multi-roll forming machine, directly connected by a removable length of belt conveyor. This machine has been built to T.I. design and is driven by a 60-h.p. motor. A typical product is standard corrugated sheet up to 12/3 in. pitch in width.

Certain applications call for specially flat or panel-quality sheet, and to achieve this additional accuracy sheets taken from the Halden lines are subjected to roller levelling or, alternatively, to hydraulic stretching. Rhodes intermediate shears with hydraulic hold-down equipment are installed for dealing with hot-rolled blank taken direct from the hot mill. For accurate side and end trimming of sheets which have been roller or stretcher levelled, a Stamco fully-automatic shearing line, by Head-Wrightson, is available. This consists of four guillotine shears set out in the form of a rectangle, two shears being moved bodily in relation to the others by electric power for size adjustment.

Other finishing equipment includes a Yoder precision slitting machine which incorporates pull-through re-coiling equipment. There is also a section devoted to circle blanking and cutting, to cover a wide range of sizes, and slugs for impact extrusion are processed in the same section.

Flash annealing, in which the sheet is raised to the annealing temperature and held there a few minutes only, in order to avoid grain growth, is finding increasing



Charging end of the flash annealing furnace.

application, and the furnace for this purpose supplied by Stordy Engineering Co., Ltd., has an overall length of some 100 ft. It consists of a heating chamber, through which air preheated by means of external electrical resistance heating elements is circulated. Sheets, circles or blanks are fed through the furnace at a predetermined speed on a series of heat-resisting tapes supported on rollers. From the heating chamber, the material being treated passes directly to a cooling chamber, from which it finally emerges for stacking.

#### Oil Cooling Equipment

For the hot mill line the soluble oil system consists of a 50,000-gal. storage tank equipped with electric immersion heaters to maintain constant temperature of the fluid, particularly at week-end shut down, and to remove any excessive heat a cooling tower is provided. Two Pulsometer 120 h.p. centrifugal pumps circulate the soluble oil to the mills at the rate of 2,000 gal./min., at a pressure of 60 lb./sq. in. From the mills the soluble oil drains into glazed cooling and filtering tanks, from which it is pumped to the cooling tower by two Sulzer vertical spindle pumps.

An oil cleaning plant is installed to serve the two 4-high strip mills, three Harland Duoglide pumps delivering oil to the mills, and three similar pumps taking oil from the draining tanks to a battery of Lilos twin-cartridge strainers, each of 3,000 gal. capacity. From the strainers, the oil goes to a 10,000 gal. tank from which it is passed through four Steller filters to a final storage tank for re-circulation. A similar but smaller plant is installed to service the 2-high temper mill.

#### Electricity Supply and Equipment

The electrical supply for the works is taken from the national grid at 66,000 volts., and transformed down to 6,600 volts. by means of two English Electric 15,000 kVA outdoor transformers. The 6,600 volt supply is controlled by a remote-operated 250 MVA switchboard comprising 2-1,600 amp. incoming circuit breakers and 3-800 amp. outgoing circuit breakers, also by English Electric. From the main switchboard a 0.15 sq. in.



Multi-roll forming machine.

cable supplies power at 6,600 volts to the foundry where two 750 kVA Metrovick transformers reduce it to 415 volts.

The rolling mill is supplied by a ringmain comprising two 0.3 sq. in. Johnson & Phillips aluminium-sheathed cables in parallel. Ring main switchgear units are installed at load centres, all main drives being taken directly off the 6,600 volt circuit. Low tension A.C. power is obtained from three 1,000 kVA and two 750 kVA English Electric transformers, all wound delta-star with neutral solidly earthed.

The three 1,000 kVA transformers feed into a 17 panel English Electric air-break switchboard, each outgoing circuit having the usual over-current protecting and earth leakage relays. The switchboard is in three sections, coupled by bus-section switches which are normally open, except at week-ends, when one transformer is usually sufficient to cover the works requirements. The two 750 kVA transformers normally run in parallel, controlled by two 1,600 amp. incoming oil immersed circuit breakers and three 800 amp. outgoing circuit breakers supplied by George Ellison & Co., Ltd.

Power for small tools and portable lights is obtained from 3 kVA double wound 415/110 volt Heavyberd transformers, the secondary centre point being solidly earthed. These transformers are installed at numerous points throughout the works, and provide protection against the possibility of dangerous electric shock. Three-phase welding plugs are also installed throughout the works, and these obviate the use of long trailing cable.

For overhead travelling cranes, variable speed D.C. motors on the process lines, mill screwdowns, and other applications, direct current at 460 volts is obtained from a 750 kW Metrovick mercury arc rectifier, comprising four 163 kW glass bulb rectifiers and two 62.5 kW balance rectifiers. The D.C. is controlled by a 14 panel flat back slate switchboard of conventional type with electronically controlled loading resistance.

For the new sheet mill annexes, the ring main is extended to supply a 1,000 kVA outdoor transformer to provide a low tension supply for the mill drives and ancillary, plant by Metropolitan-Vickers Electrical Co., Ltd.

## C.D.A. Coming-of-Age

**S**PEAKING at a luncheon held recently at Kendals Hall, Radlett, Herts., to mark the coming-of-age of the Copper Development Association, Lord McGowan, K.B.E., remarked that because he had been a friend of the C.D.A. since its inception he was well aware of how successful it had been during the past twenty-one years. The membership had risen from 25 to 34, and as the years passed, more and more people, not only in this country but in many other countries, had come to recognize in the C.D.A. a guide, philosopher and friend. In more than one field, today, the Association was acknowledged as a leading authority, and was consulted by Government and official bodies as well as private firms and persons. The C.D.A. technical staff were among the best in the world for the job they had to do, and had at their fingertips, in the well organised reference library, a comprehensive system of information carefully culled from the world's leading publications on the subject.

As another invaluable part of its work, the C.D.A. acted as watch-dog on behalf of the copper-using industries over a wide range of standardisation activities. Members of the staff served on more than sixty technical committees and sub-committees of the British Standards Institution.

Lord McGowan went on to say that, too often, in the past, our educational institutions—fine though they undoubtedly were—had tended to look upon the technical student as a poor relation. That was an attitude of mind we could no longer afford, and he was glad to say, it was now recognised that proper technical training before a man started his working life, and continuous training during it, were two of the most important keys to higher productivity. Also, from experience gained on his frequent visits abroad, he believed that commercial salesmen in many industries must have their work supplemented by technicians to show customers how best to use the products with which they were dealing.

He made a plea, therefore, for a closer association of science with industry. The C.D.A. could well congrat-

ulate itself on the work it was doing in that sphere. Other industries might lag behind technologically because they had never set up machinery to make the results of research known to individual concerns in their particular field. That was not true of copper. It said much for the industry that it saw the need for such machinery as long ago as 1933, and by forming the C.D.A. took steps to meet it. The Association was performing, and would continue to perform, a valuable service to British industry.

Mr. R. L. Prain, O.B.E., Chairman of the Council of the Association, announced the setting up of a trust fund to secure the future of the Association. The fund, which would amount to not less than £100,000 would be subscribed by the following—Roan Antelope Copper Mines Ltd., Mufulira Copper Mines Ltd., Nchanga Consolidated Copper Mines Ltd., Rhokana Corporation Ltd., and the British South Africa Company. It would be a Rhodesian trust, administered in Rhodesia by trustees representing the donors and the Association.

## Correspondence

### PRESENTING A TECHNICAL PAPER

The Editor, METALLURGIA.

Dear Sir,

May I reassure aspiring authors not to be unduly disturbed by Mr. J. F. Kayser's letter in the May issue. The speaker on a technical subject who can talk for an hour from brief notes is unusual, and unless gifted, far more boring than the author who reads his paper.

Further reassurance is to be had from the fact that Sir Winston Churchill reads most of his speeches: so much depends upon what has been written and the manner in which it is read!

Yours faithfully,

R. J. Brown,

Chief Chemist and Metallurgist,  
Morris Motors, Limited.

Coventry,  
June 10th, 1954.

# Induction Melting of Metals

## Normal and High Frequency Equipment Surveyed

*Marked progress has been made in the last few years in the application of both normal frequency and high frequency induction power for melting and heat treatment. Following a visit to the United States, Mr. J. C. Howard, of Electric Furnace Co., Ltd., recently gave a lecture in Birmingham on the latest developments in this field. The following account is confined to that part of Mr. Howard's lecture dealing with melting applications.*

**T**HE principles of induction heating are now widely understood, and it is sufficient to recall that the induction method causes current to flow in the workpiece and that this workpiece is heated by its own resistance to the current flow. It is the job of the designer of the equipment to see that the power is most effectively and efficiently applied. Whenever possible, normal frequency power is preferred to high frequency power for two reasons: (1) the capital cost of the plant is less, owing to the absence of any type of frequency converter; and (2) the operating cost is less, chiefly owing to the absence of the losses inevitably associated with the frequency converter. High frequency power is applied only when necessity, convenience or simplicity of application justify the extra costs.

### Normal Frequency Cored-Type Furnaces

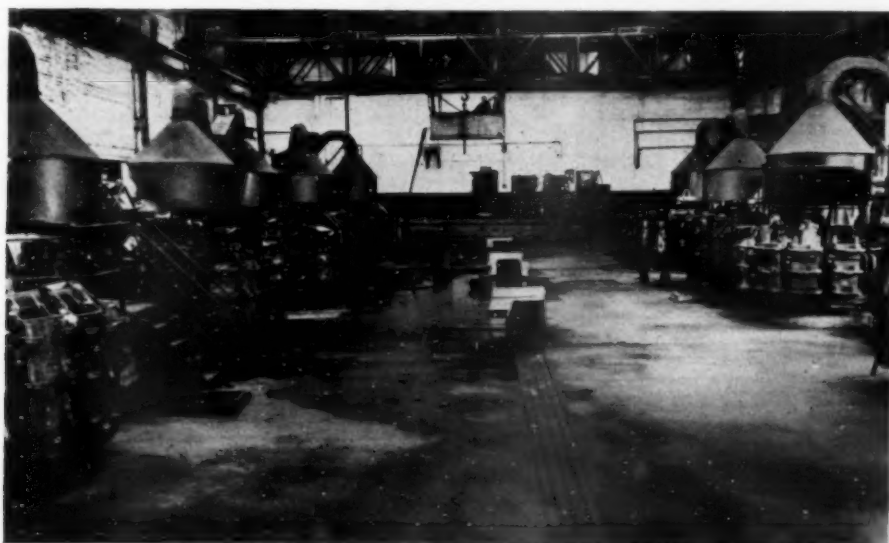
The Ajax-Wyatt furnace for brass melting has been in use for more than 25 years and today over 95% of the brass required for hot working is produced in furnaces of this type. It is a normal frequency iron-cored furnace with the primary coil surrounding one limb of the core, and surrounding this is the loop of molten metal embedded in the refractory. The heat is generated in this loop of molten metal, and is transferred to the bath above by the movement of the metal set up by the motor effect of the current and ordinary convection.

These furnaces are often arranged to cast direct from the furnace into cast iron ingot moulds mounted on

turntables which can be rotated in front of the furnace, and large tonnages of brass are now produced by continuous casting from metal melted in this type of furnace. Fume hoods are universal for removing the copious fumes given off during certain periods of the process. The furnaces may be either mounted on stages or let into a pit, but it is preferred to mount them so that the top of the furnace is flush with the platform staging, since this makes charging so much simpler.

Recent years have seen a great increase in the maximum size and rating of this type of furnace, and there are now installations in this country with ratings of 600 kW., melting at a rate of 2-3 tons per hour: for large castings capacities of 20 tons of molten metal are available. The larger furnaces have two transformer units which can be supplied by means of a Scott-connected transformer so that a balanced 3-phase load is taken from the mains.

The normal frequency, cored-type furnace has been modified for the melting of aluminium. In one form, two chambers are used, into one of which the metal is charged and from the other of which the molten metal is ladled. The two chambers are connected by two channels surrounding which is the furnace transformer. This furnace has been specially developed to operate in conjunction with die-casting machines to avoid separate melting equipment. The power input is automatically controlled to maintain the correct temperature. Aluminium brings some of its own special problems, one of which is a tendency for the channels to choke with



Battery of Ajax-Wyatt furnaces for brass melting.

alumina. These channels are designed so that they can be easily cleaned with suitable scraping tools without emptying the furnace. The two-chamber furnace has a rather higher radiation loss than a single-chamber furnace, so when a central melting unit is used in a large die casting shop to feed a number of holding units adjacent to each press, then a modified form of single chamber furnace, with less surface area and consequently lower radiation loss, is available.

### Erosion Problem

The normal frequency, cored-type furnace is the most efficient form of electric melting furnace, and would be used for melting all types of metal, but for its two main disadvantages, which are :—

- (a) The necessity of maintaining molten metal in the slot from charge to charge. This means that this type of furnace is not suitable for conditions where the composition of the metal varies constantly and there are no long runs on one alloy; nor is it suitable for day shift working.
- (b) The severe erosion of the slot when dealing with the higher melting point metals.

Recently, progress in the type and make-up of refractories has enabled nickel-silver, copper-nickel, phosphor-bronze and copper, etc., to be dealt with satisfactorily and, although it is still uneconomical to deal with steel, there are cored-type furnaces operating on cast iron—both for straight melting and for the superheating of cupola-melted metal. Naturally the higher temperature and the more erosive nature of the metal result in shorter refractory life, and the problem has, therefore, been tackled in a way rather different from that applied to non-ferrous melting, the furnace design being such that a worn lining can be replaced much more speedily. The inductor loop is more or less

horizontal and behind the melting chamber, and when relining is necessary the winding and core, which are specially designed for quick removal, are taken out, the top Sindanyo board above the transformer section is lifted off, and the old refractory dug out and discarded. In relining a dry grist, similar to that used in the Rohn method of lining high frequency furnaces, is quickly tamped into position on the furnace bottom until slot level is reached, and then a cast iron former—easily made in any foundry—is placed in position and more refractory material tamped round it layer by layer. The lower part of the main chamber is formed in a similar way, but the upper part is finished off with a cold setting plastic cement such as ganister. Relining can be accomplished in about 4 hours, and since the furnace is mounted in a cradle, it is quite possible to carry a spare body which can be exchanged with an existing one in an hour or so.

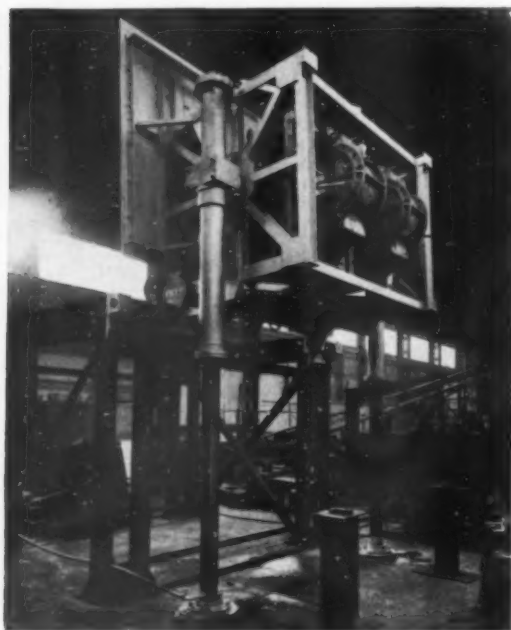
There is no reason why this revised technique should not be extended to the more difficult non-ferrous metals. One of the main reasons for having the loop under the crucible in the original Ajax-Wyatt furnace was to keep a good head of metal above the slot. The operating temperature approaches the boiling point of zinc and the resulting zinc vapour pressure, coupled with the pinch effect, would cause repeated interruption of the power input were the slot to be placed horizontally. There is, of course, no such tendency with alloys containing no volatile constituent.

### Coreless Induction Furnaces

The normal frequency, coreless induction furnace, which is being increasingly talked about, may be fed through a phase converter, thus giving a balanced load on the 3-phase supply. It is generally similar in construction to the high frequency furnace and, in fact, it has reached its present stage of development largely from the wealth of information and experience that has been made available from high frequency furnace operation. For small and medium furnaces, high frequency energy is preferable. It makes possible smoother control of power input, it is easier to melt from cold any shape or size of raw material, and the wear and tear on the refractory lining is less because there is less stirring. For larger furnaces, however, and especially for some alloys, such as cast iron, with melting points lower than steel, a case can be made for accepting the inconvenience of the normal frequency coreless type of furnace instead of the high frequency furnace, since both the initial cost and the power costs are considerably lower.

From a metallurgical point of view, the stirring may be too severe, and it seems unlikely that this type of furnace will be satisfactory for steel making since, with heavy stirring, it is impossible to keep the metal covered with molten slag and to prevent oxidation. By putting the level of a full charge well above the furnace coil, the meniscus is reduced in the final stage of the melt but this does not, of course, reduce the stirring and possible oxidation during the earlier stages of melting. A similar criticism may apply to some non-ferrous melting.

In the coreless normal frequency furnace, it is found in practice that when melting from cold the size of the scrap must be limited, pieces not less than 6-8 in. diameter being the most desirable. This difficulty can be partially overcome by leaving in the furnace, a heel of molten metal after each cast. Small material such as borings and turnings, can then be melted by feeding it



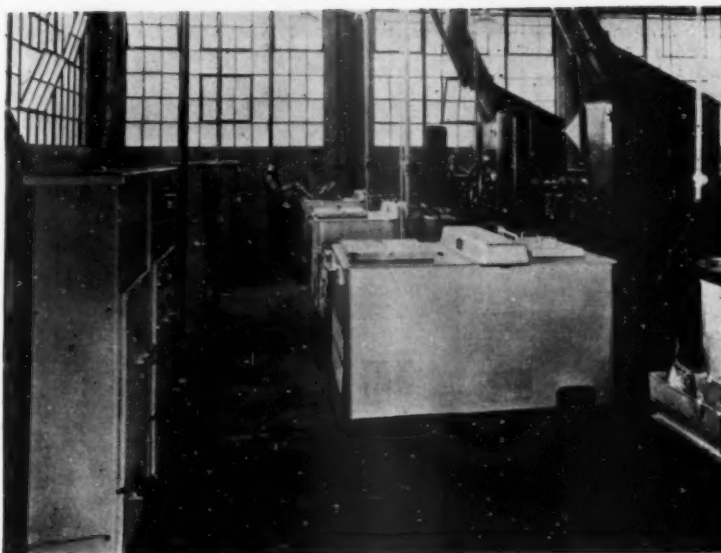
Two-ton 600-kW. two-slot Ajax-Wyatt furnace for brass melting undergoing tilting trials at maker's works.

into this pool. Once the charge is molten, there is no difficulty in superheating apart, of course, from the excessive stirring characteristic of the lower frequency. It can be seen, then, that this type of furnace is suited to the superheating of cupola metal, but it must be added that it is much more suited to "batch" heating than to continuous heating, where metal is trickling in from a cupola all the time, and being taken out at intervals. This is because the energy induced into this type of furnace is dependent on the volume of metal within the coil, and when this volume is varying, the power input will need constant adjustment. This difficulty does not, of course, arise with the cored-type low frequency induction furnace, where the energy is induced in the fixed volume of metal in the slot, or with the arc furnace, where the regulator looks after the power input automatically. Each of these furnaces is suitable as a mixer for operating in conjunction with the cupola, and the selection of the right type of furnace must depend on the circumstances of each individual case.

### Cast Iron Melting

In considering the electric melting furnace in the cast iron field, the emphasis should be on duplexing. The cupola is very efficient and has a lower conversion cost than any other furnace but, its product can vary in temperature and composition almost from minute to minute. Moreover, if much coke has to be burnt to give superheat, there is serious sulphur pick-up. Where relatively high-quality castings are required, as, for example, in the motor car industry, duplexing with the correctly selected electric furnace can be strongly recommended. The capacity must be enough to even out irregularities in the composition of the metal, and the power rating must be sufficient to give the degree of superheat necessary.

In the finishing of the motor car castings already mentioned, large quantities of cast iron borings are produced. These are poor raw material for the cupola and so are of low commercial value. They can, however, be very efficiently melted in induction furnaces. The arc furnace is not so suitable for the metallurgical reason that the charge commonly loses carbon as it melts out and finishes at 2.8-3.0% carbon. Great difficulty is experienced in an arc furnace in carburising such a melt regularly to the 3.3-3.5% carbon that may be required for grey iron castings. Recarburising in the induction furnace is relatively simple, because the constant agitation of the bath makes for rapid absorption of any carbon or graphite added on its surface. To date the high frequency furnace has been the world's preference for this type of work, as it is for making cast iron synthetically from steel scrap. Sweden, cut off during the war from her normal supplies of pig iron for foundries, resorted to this technique and also melted cast iron borings in this type of furnace. To-day, the largest high frequency furnaces in Sweden are used for making cast iron.



Battery of 40-kW. Efco-Lindberg two-chamber furnaces in aluminium die-casting shop.

One great advantage of the high frequency furnace is the small volume of the refractory lining relative to the charge it contains. This makes this type of furnace eminently suitable for intermittent working, there being only some 10% difference in power consumption between starting with a hot furnace and starting with a cold one. For furnaces up to 10 cwt. or even 15 cwt. capacity, a construction using a framework of bronze angles and T-sections bolted together with electrically insulated joints suitably placed to prevent the framework being heated by induced currents is quite adequate. The furnace coil itself is mounted in an asbestos cement framework, and properly located in the furnace body by large asbestos cement blocks. Larger furnaces are preferably made with a steel body protected by a magnetic shield to prevent heating of the body.

The spark gap type of high frequency furnace equipment uses replaceable crucibles with capacities up to about 20 lb. This forms an ideal unit for research or experimental work. The lift-off type of furnace, in which the inductor coil in its box can be lowered over a crucible containing the metal, has the advantage that contamination can be avoided when melting different alloys. As soon as one charge is ready for pouring, the coil can be lifted, the bogey moved over so that a freshly charged crucible comes into position to have the coil lowered over it. Melting is restarted at once while the last charge is being poured. Where two or more furnaces of the usual tilting type are used with one high frequency generator, a furnace changeover switch is used so that the power can be quickly changed from one to another. As with the Ajax-Wyatt type it is desirable to keep the furnace platform clear of all obstructions so that the furnace is just a "hole" in the ground, thus making charging easier.

### Some Applications

High frequency furnaces are, of course, widely used in Sheffield in the quality steel industry, and they have, in fact, almost entirely replaced the old crucible process

for tool steel making. It is remarkable the small amount of floor space that is required with a high frequency furnace installation. One 150 kW. installation with one 5 cwt. and one 10 cwt. furnace including moulds, ladles, etc., occupies only 200 sq. yds. and can turn out 20-25 tons of high grade steel ingots per week—steel worth, say, more than 5s. per lb.

Where good raw material or scrap containing expensive alloys is available, the high frequency furnace competes economically with the arc furnace, largely because there are no electrode costs, which amount to approximately 15s. per ton of steel. In the non-ferrous industry, the high frequency furnace is used for the melting of those metals and alloys—such as nickel and the nickel-chromes—whose melting point is too high for the Ajax-Wyatt furnace and, in addition, it is used by those firms who have short runs of alloys of differing compositions for which conditions the Ajax-Wyatt Furnace is not suitable, because its slot must be left full of metal.

A very poor power factor is inherent in the coreless induction furnace. For this reason, a large bank of capacitors, some of which must be variable to deal with the varying power factor, is essential. Normal frequency capacitors are much more expensive than those for use at high frequencies. The largest high frequency furnace

installation so far installed is about 3,500 kW. with a furnace of 12 or 15 tons capacity. It may be that this is somewhere near the limit in rating because of this question of the power factor. It may be less than 0.1 so that 3,500 kW. means the kVA rating will be 35,000. With any safely usable voltage, this means that very high currents have to be fed into a very small space, thus setting a limit to what is possible.

As already mentioned, the high frequency furnace, despite its high initial cost, has its role to play in the cast iron industry. One excellent example is provided by an installation in this country, with a 650 kW. generator which can be coupled to either one of two 2-ton furnaces. The furnace charge is made up of 90% cast iron borings and 10% heavier well-insulated material to help the borings to sink down. The production rate is about 1 ton per hour, and the furnace works 24 hours a day feeding into a gas-fired mixer of 10-15 tons capacity. The foundry draws its metal from this mixer and works only a day shift. The scheme utilises the expensive high frequency equipment to the fullest possible extent, and, moreover, cheap cast iron borings—worth 30-40s. per ton are used instead of pig iron at some £12-15 per ton. The cost of this installation was paid off in a little over a year from the savings thus made.

## B.W.R.A. Summer School

THE Summer School on Welding, organised by the B.W.R.A., has now become an annual event. This school, the fourth of its kind, was held, as in previous years, at Ashorne Hill, near Leamington Spa. On this occasion it was held from Monday, June 14th, to Saturday, June 19th.

The general theme was fairly wide—"Welding Design and Practice" and a general plan was followed of giving lectures of general interest in the mornings, with lectures of more specialised interest to smaller groups in the afternoons. The 170 students who attended the school were divided into the following groups, to meet, as far as possible, their individual requirements:—

- (a) Welding design and production planning in the heavy engineering industry.
- (b) Welding design and production planning for sheet metal fabrication.
- (c) Welding practice in heavy engineering.
- (d) Welding practice for sheet metal fabrication.
- (e) Shipbuilding.

Thirty lectures in all were given during the week by specialists in various branches of welding, from both academic and industrial organisations. The organisers counted themselves fortunate to include in the programme a lecture on corrosion in relation to welded construction, by Dr. U. R. Evans, F.R.S. Amongst other innovations a lecture was also given on the important subject of the control of distortion. More attention was given to the gas-shielded self-adjusting arc process than in previous years, because of its growing interest and popularity.

To supplement the lectures, some practical demonstrations of welding and cutting processes were organised on a fairly ambitious scale, with the collaboration of some of the leading industrial exponents of the various methods and equipments involved. These included demonstrations of two different sets of equipment for gas-shielded self-adjusting arc welding, now being made

by British manufacturers. As in previous years, discussions of topical matters and technical film shows were arranged for the evening sessions.

Perhaps the most important lesson that was learned was that the demand to attend the welding school remains very high. The Association very much regretted that nearly 100 applicants had to be turned away, the school being fully booked by early March of this year. Every effort is being made to increase the number of students that can be taken at the school, but in spite of this, there is little doubt that places will be filled up early next year. Anyone interested is therefore invited to make early application to the organising secretary.

## Tallest Commonwealth Chimney

SOARING 615 ft. above a base 22 ft. high, the chimney for the iron ore plant of The International Nickel Company of Canada, Ltd., will take the title of "tallest in the British Commonwealth" which for many years has been held jointly by the two 500-ft. stacks at Inco's Copper Cliff smelter. The great height of the chimney at the new plant is to ensure proper diffusion of waste gases in the upper atmosphere.

The new plant will make metallurgical history by recovering high-grade by-product iron ore from nickel ores mined in the Sudbury District. It will use a process developed by Inco's research staffs, and the iron ore will be higher in grade than any now turned out in quantity in North America.

The chimney is being built of reinforced concrete, lined throughout with special brick, and will weigh 17,000 tons. It will contain over 500,000 lb. of reinforcing steel and nearly 100,000 lb. of insulating material. The stainless steel coping for the top of the shell will weigh 9,000 lb. Inside diameter at the top will be 30 ft., and outside diameter at the base will be 63 ft. 3 in. Construction of the stack will be completed about the end of the year.

# Sir William Siemens

## A Pioneer in Electricity and Regenerative Heating

By Eric N. Simons

*The family name of Sir William Siemens is preserved in the names of a number of electrical engineering firms in this country, but in the metallurgical field he is always associated with the regenerative open hearth furnace and with the Siemens-Martin process for making steel. In the following brief biography, reference is made to his activities in these and other fields.*

IT is characteristic of technical affairs that men whose work has revolutionised an industry frequently give their names to a particular process or product, with the result that ultimately these names become household words (or, if this is considered a misnomer, familiar words) in the industry to which they devoted their lives. To such an extent is this so that newcomers into that industry often do not realise that the name of a process or product relates to a person, who once lived as fully as they. Young metallurgists, for example, talk freely of 'austenite' and 'martensite'; young steelmakers discuss the respective merits of Siemens-Martin and Bessemer steels; yet rarely do they pause to remember that austenite derives from Austen, martensite from Martens, and that Siemens and Bessemer were men of fame in their day.

With the possible exception of Bessemer, few names are more frequently on the lips of steel men than that of Siemens. Sir William Siemens, to whom they often unwittingly refer, was a man of extraordinarily diverse talents, and his life was one long record of hard work, prolific invention and enormous achievement. German by birth, or perhaps it would be better to say Hanoverian—since Germany in his day was made up of separate principalities, loosely linked by race and speech—he first opened his eyes in the little town of Lenthe, Hanover, in 1823. He was christened Carl Wilhelm, but his elder brother was also called Carl, so he was usually known by his second name. His father was a farmer of government lands, and there were in all eight sons in the family. Of these, no fewer than four were eventually concerned with scientific pursuits.

Siemens' father died in 1839, and responsibility as head of the family devolved upon Werner Siemens, a young man of 23, at that time an officer in the army of Prussia. Werner shouldered his new tasks manfully, and under his guidance all the family came to manhood. At first Wilhelm was sent to a commercial school at Lübeck, whence he passed to the technical school at Magdeburg. He already showed a mechanical bent, and after finishing his term at Magdeburg, went to the University of Göttingen, where he studied under Himley, Wöhler and Weber, as well as a fourth professor who was his brother-in-law.

### Early Inventions

On completing his studies, and having expressed the desire to become an engineer, he was able, through the good offices of his brother Werner, to secure a post in the Stolberg factory at Magdeburg in 1843. Werner was also keenly interested in science, and he and Wilhelm collaborated in the working out of various ideas. They experimented with what was to them a novel use for electricity—the deposition of metals—and busied

themselves for some time in improving this process, using a thermo-electric battery to provide the current. They also produced an improved solution for gilding and silvering.

The two brothers now sought a likely place for the establishment of their invention. England was at that time far in advance of other European countries in electroplating, so they decided to sell it there. Wilhelm accordingly came over in 1843 for this purpose. He knew so little English that he first called upon an *undertaker*. The German 'Unternehmer,' literally translated, is 'undertaker,' but really means a 'contractor' or person who 'undertakes' a financial enterprise. There is no record of who the undertaker was or what he said on being approached. Despite all his handicaps, however, Siemens disposed of the invention to Messrs. Elkington for the sum of £1,600.

The brothers, not unnaturally, thought they were on the high road to fortune, so Wilhelm gave up his job at the Stolberg factory in 1844, and returned to England to dispose of two further inventions—a chronometric governor for steam engines invented by Werner and worked out by Wilhelm, and a process of anastatic printing, invented by Baldamus of Erfurt and later developed by the two brothers. Wilhelm was, however, quite unsuccessful. No one would pay the price demanded, and both inventions failed to establish themselves. Nevertheless, the chronometric governor had merit, but was too delicate an instrument for practical purposes. The Society of Arts awarded it a prize in 1850, and it was similarly honoured at the great Exhibition of 1851. Eventually it was applied, by George Airy, to the regulation of the movements of certain instruments at Greenwich Observatory.

The anastatic printing process was essentially a transfer process. The page to be reproduced was damped with acid and laid upon a metal plate. Pressure was then exerted, causing a slight etching of the metal by the acid in those parts that came into contact with the unprinted portions of the paper. There was also a slight setting off of ink from the print. Plates could then be linked up and printed by lithographic methods. The process, though used for a considerable period, was eventually displaced by photography. As Siemens had found no one to back the invention, he started a factory himself, but lost much money.

### Regenerative Engines and Furnaces

Having spent five disappointing years in Britain, he thought seriously in 1849, of joining the Californian gold rush with two of his brothers, but, fortunately for the steel industry, he abandoned the idea. During these years, he had been working on a regenerative steam engine and condenser, of which he must be considered the

inventor, although the notion was not entirely new. The principle of this engine was thoroughly sound. Much energy was being lost in steam engines because of the high temperature at which the products of combustion were discharged, and also by the condensation of the steam to water after only part of the heat had been employed as energy.

Siemens arranged for the steam, after serving its purpose in the cylinder, to pass through a metallic device, to which it imparted a large share of its heat. Thus, it reached the condenser in a partly cooled condition. The water from the condenser was afterwards forced back through the device, absorbing its heat and thus reaching the boiler with its temperature already raised to some extent. The first application of this novel principle was, however, unsuccessful. Twelve years of hard work and mechanical ingenuity were expended by Siemens on this idea. His first patent was taken out in 1847, and the invention was not finally discarded until 1859. It never fulfilled expectations, but it enabled Siemens to keep alive and work out other ideas during this period. This was because a large engineering firm in Manchester, Fox and Henderson, paid him a good sum of money for a share in the patent.

Not until 1851, seven years after his return to England, did real success arrive, through the invention of a water-meter which admirably fulfilled its purpose and brought in a good income from royalties. Wilhelm and another brother, Frederick, now endeavoured to apply the principle of their condenser to manufacturing processes, and more particularly to those in which large quantities of liquid needed to be evaporated, as in salt-making. They next applied the principle to furnaces, and Frederick took out a patent on these lines in 1856.

The products of fuel burned in furnaces used to go straight up the chimney and to waste. The Siemens' idea was to lead them through a chamber filled with refractory brickwork which deprived them of their heat. As soon as the chamber was sufficiently hot, the current was shut off and the air supply of the furnace introduced into this chamber. The air thus came to the burning fuel hot instead of cold. By the use of two chambers employed alternately to absorb and give out heat, the process was made continuous. A later improvement arising from the use of gas instead of solid fuel was to pass this gas through a regenerator so that it reached the point of combustion in a highly heated state. This saved an impressive amount of heat. The gas could be made from fuel of lower quality than previously, and operations hitherto only possible in crucibles heated by solid fuel could be carried out in an open furnace.

#### Application to Steelmaking

1857 saw the first practical application of the Siemens regenerative furnace to the melting and reheating of steel. Shortly afterwards, the same principle was applied in a slightly modified way to the warming of the air for blast furnaces. It was next used in glass-making, and eventually the principle was extended to many industrial processes requiring heat. Finally, and most important of all, it was used to make steel, either by melting wrought iron and cast iron together on the open hearth of the furnace, or direct from iron ore. The first was known as the Siemens melting process, and the second as the Siemens iron ore process.

The Siemens process for making steel was first employed in 1865, or 1866. By 1882 no fewer than four

million tons had been produced by it. As compared with 11 million tons produced by the Bessemer process in 1896, the world output of Siemens steel was 7 million tons. To develop the process and test it on a big scale, Siemens and his friends put down works in Landore, South Wales, but these did not prove successful and were abandoned in 1888.

Naturalised in 1869, Siemens won many honours. He was awarded medals by the Exhibition in London in 1862, and by that of Paris in 1867. In 1860, he was made a Member of the Institute of Civil Engineers in special recognition of his merits, and in 1862, he was elected a Fellow of the Royal Society.

Electricity was now occupying the attention of engineers all over the world, and Siemens turned his attention to it. His brother Werner was already engaged in similar investigations, and had founded the firm of Siemens and Halske (1847), which was to become one of the greatest electrical firms in the world. William Siemens, as he was now known, was the London agent of this firm, and in 1858, its business had reached such magnitude that a small factory was established in England at Millbank. The Siemens works were later transferred to Charlton, Kent, under the name of Siemens Brothers (Werner, Wilhelm and Carl.) This firm laid the first transatlantic cable in 1874, and although William Siemens had had little experience of marine engineering, he designed the cable ship, 'Faraday,' used for laying this cable.

#### The Dynamo

In 1867, three inventors simultaneously announced their discovery of the modern dynamo—William Siemens on behalf of Werner; Sir Charles Wheatstone; and Cromwell F. Varley. Siemens Bros. played a large part in developing this invention, and also experimented with the provision of electric light for domestic and civic use. William Siemens was among the first to suggest the transmission of power by electricity and to use it for locomotive purposes on the Portrush Railway (1883).

It is not commonly known that he invented an electric furnace in 1879, but for a long time it came to nothing. Among other inventions for which he was responsible was the bathometer for ascertaining sea depths without a sounding line, a clever device that nevertheless failed to find practical employment. He also designed an electrical thermometer for recording temperatures at inaccessible or nearly inaccessible points, particularly in deep sea investigation. He studied the effect of electric light on plants, and in 1855, took out a patent for producing extremely low temperatures by the expansion of liquefied gases already cooled down to the lowest attainable point, showing that he had grasped the principle of refrigeration. Altogether, he took out no fewer than 113 engineering patents, and there is a record that he also indulged in speculations as to the energy of the sun and its origin.

Other honours now fell to him. President of the Mechanical Section of the British Association in 1869, and of the Association itself in 1882, he was also chosen President of the Society of Telegraphic Engineers twice (1872 and 1878). In 1877, he became President of the Iron and Steel Institute. He was Chairman of the Council of the Society of Arts in 1882. The University of Exeter awarded him an honorary D.C.L., and the Universities of Dublin and Glasgow made him honorary LL.D. He received the Albert Medal of the Society of

Arts in 1874, and the Howard prize of the Institute of Civil Engineers in 1883. The Bessemer Medal of the Iron and Steel Institute was awarded him in 1875. He was also a member of the French Légion d'Honneur, and received the honour of knighthood in 1883, the year of his death. He died on 18th November, and was buried in Kensal Green after a service at Westminster Abbey, where there is a window to his memory.

He had married in 1859, Ann, daughter of Joseph Gordon, of Edinburgh, but had no children. His many inventions and their successful application brought him a considerable fortune, which he employed in making liberal endowments for the benefit of science and engineering. Lady Siemens, after his death, founded the Siemens electrical laboratory at King's College, Cambridge.

## Institution of Metallurgists

### Mr. W. Barr's Presidential Address

IN taking over the Presidency of the Institution of Metallurgists at the recent Annual General Meeting, Mr. W. Barr, Chief Metallurgist and an Executive Director of Colvilles, Ltd., said he was mindful not only of personal but of national honour—"for am I not the first of the line from the other side of the Tweed." As a Scot, Mr. Barr said he was particularly impressed at that moment with his responsibilities in upholding a tradition, for in his Presidential Address six years ago, Dr. Maurice Cook used these words: "We now have our Professional Institution, and we must, as the years go by, establish a tradition worthy of metallurgists of our generation, which we, and those who follow us, can contemplate with satisfaction and pride." The Institution could claim at least to have laid the foundations of a tradition, the keynote of which was "service."

In the early years the Presidential Addresses were devoted to a discussion of the work of the Institution and of its future hopes and prospects, but in 1952 an entirely new note was struck when members were privileged to hear from Professor O'Neill, a notable contribution on "Cultural and Professional Aspect of Metallurgical Training." Last year Dr. Pfeil gave an illuminating address on some of the metallurgical developments of the last thirty years. Mr. Barr continued: "As we enter upon the tenth year of our existence, I am faced with the problem of which kind of address would be more appropriate and helpful—should I follow the earlier examples or the more modern ones, in other words, do we need at this juncture a metallurgical or a domestic note in the Presidential Address? I have decided upon the latter. As your new President, I am in the happy position of being able to look back upon a record of achievements of which we can all be justly proud."

During the early years of the Institution's growth, both officers and members were concerned in the regulation of its activities and about the promotion of its further development. The founders of the Institution (of whom only six were still on the Council) had set high standards of ethical and professional conduct, and high educational standards for admission to all grades of membership. The maintenance of these standards in a manner becoming an important professional body demanded firmness of purpose in the face of many temptations to relax standards for the sake of house-keeping.

The framing of the Institution's regulations for admission constituted a *magnum opus*, and the Institution owed a great debt of gratitude to those whose knowledge,

wisdom and foresight produced so important a document, on which time and experience had not wrought any major modifications. The membership continued to grow at a steady rate of about 200 per annum and there was no sign of decline. The Institution aimed to include in the various grades of membership all those who were qualified metallurgists, using the term widely enough to include any who contributed in any way to the science or practice of metallurgy. The extent of the Institution's useful activities depended upon the membership, and as the latter grew, so also would the former expand.

Entry into membership by way of the Institution's Examination was being sought in increasing measure. From the early days, when candidates for examination numbered fewer than 20, to last year, when there were 240 registered applications, represented a twelve-fold increase in about half as many years. For the current year, the registered applications were over 300, which was very satisfactory.

A good many applicants for membership were seeking partial or total exemption from the Institution's examinations. In the case of those submitting metallurgical qualifications awarded by universities, the granting of exemption was provided for in the regulations. Certain other certificates were also acceptable, but there still remained a number of diplomas, the standards of which had yet to be ascertained in relation to known standard examinations or to the Institution examination. A new Board of Metallurgical Studies and Examinations had been set up jointly by the Institution and the Institution of Mining and Metallurgy. The Board's membership represented many interests in metallurgy, and it was now engaged on a review of the standards and requirements of different metallurgical examinations. It was planned that the whole structure of the system of examination and studies would be examined so that there might be found avenues by which any ambitious student might progress to the limit of his capacity and appropriate quotable qualifications awarded at suitable levels of attainment.

The lectures delivered at the Refresher Course each year since 1949 had been put on permanent record in the form of printed books, available to all members at a privileged price and to the general public at the economic price. A wide range of interests had been catered for and the courses had been well supported: last year there was a record attendance at Harrogate. "It is clear that this activity is very widely appreciated," said Mr. Barr, "And I am sure you will be pleased to hear that we

are continuing the series of courses this year, and that the subject will be, "The Inspection and Testing of Metals," when I hope to see yet another record attendance at the Palace Hotel, Buxton."

"No President before me has been able to recall the successful conduct of two major metallurgical exhibitions. It is probably unique in the history of any professional body that, in less than ten years since its foundation, it has been able to sustain two such major activities opened in each case by a member of our beloved Royal Family." These exhibitions had done much to bring the science of metallurgy to the notice of the general public. The souvenir book issued at the time of the 1950 exhibition proved a best seller, and to date, about 10,000 copies had been sold.

The Institution was playing an increasingly important part in the metallurgical world, not only in the United

Kingdom, but in other countries overseas. The scope of its influence was illustrated by the fact that in the recent ballot papers circulated to members in connection with the election of office bearers, returns were made by the following countries: New Zealand, Australia, South Africa, Canada, India, Pakistan, Malaya, Brazil, Switzerland and Uganda.

It was fitting that one of the Institution's main activities was in the field of education. It was now represented on five Examination Advisory Committees, on nine Education Advisory Committees, and on five other bodies.

"In this brief review," concluded Mr. Barr, "I have attempted to present a picture of what we have accomplished in the ten years of our existence. Much has been done, much remains to be done, and I am sure that with such a record we can face the future with confidence."

## Planetary Hot Rolling Mill

### Details of Electrical Equipment for Drive

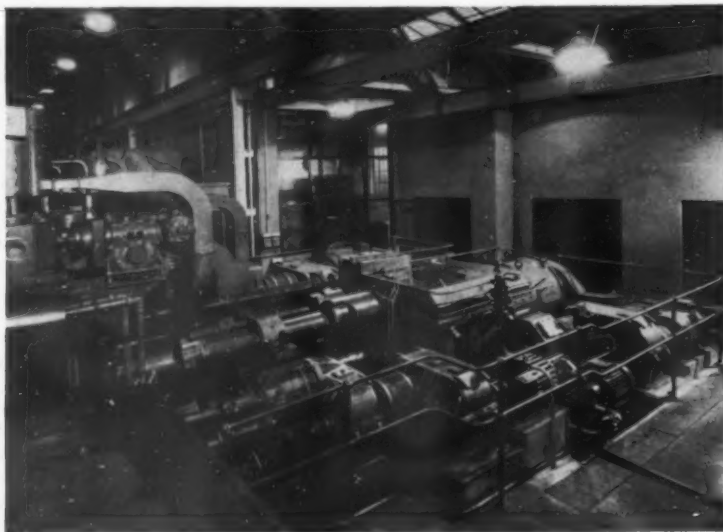
A PREVIOUS issue contained a description of the new planetary hot rolling mill installed at Wednesfield by Ductile Planetary Mill, Ltd. In the following account the electrical drive supplied by The English Electric Co., Ltd., to the requirements of W. H. A. Robertson & Co., Ltd., makers of the mechanical equipment of the mill, is described more fully.

This is the first planetary mill to be put into operation in this country and it is designed to roll approximately 10 tons of various grades of steel each hour. The rolling operation is continuous and steel slabs 15 in. wide by 1½ in. thick can be reduced to strip 0.040 in. thick in one pass. This exceptional reduction is made by a

Drive	Motor			Supply
	Type	Rating (h.p.)	Speed (r.p.m.)	
Pinch Roll .. ..	D.C.	7½	750/850	Generator 1
Feed Roll .. ..	D.C.	30	1,000/1,100	
Planetary Roll .. ..	A.C. slipring Induction	900	495	
Planishing Roll .. ..	D.C.	200	900/1,050	Generator 2
Table Rolls (2) .. ..	D.C.	5	1,000	
Coiler .. ..	D.C.	15	285/500	
Feed Roll Screwdown .. ..	D.C.	10	1,200/2,400	Generator 3.
Planetary Roll Screwdown .. ..	D.C.	5	600/2,400	
Planishing Roll Screwdown .. ..	D.C.	10	600/2,400	

single stand having two 24 in. diameter rolls surrounded by 26 planet rolls, each 2 in. diameter. The inner rolls are driven at a speed of 500 r.p.m., driving the planet rolls by friction so that the cages revolve at 228 r.p.m. The planet rolls, therefore, move over the wedge-shaped end of the slab, which is moved forward by feed rolls so that a reduction of about 0.015 in. is made as each planet roll passes over the end of the slab. It is possible to vary the ingoing speed of the mill between 4½ and 9 ft./min., and the outgoing speed of the strip between 66 and 200 ft./min.

The D.C. supply for the motors is taken from a motor-generator set having three generators and various exciters driven by a 365 h.p., A.C., synchronous-induction motor arranged to give an overall power-factor for the mill of not less than 0.95 lagging. The motor-generator set and the automatic control gear are installed in a specially ventilated room, while the mill motors, which are installed in the rolling bay itself, are forced-ventilated to exclude airborne dust. Details of the motors



Motors driving the pinch rolls, feed rolls, planetary rolls and planishing rolls of the mill. The feed roll screwdown motor can be seen on the extreme left.

supplied are given in the accompanying table.

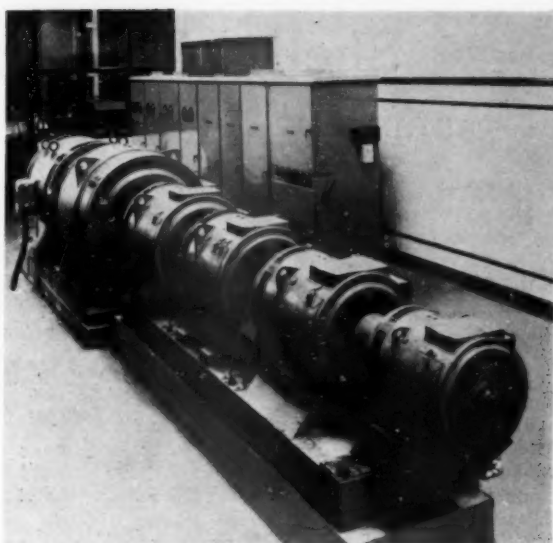
The pinch rolls are designed to run at a speed slightly faster than the entry speed of the mill. They are normally open, but are engaged by hydraulic cylinders to the leading edge of each slab to ensure that no gaps exist between slabs before the feed rolls are reached. The feed roll drive is arranged to push the slabs into the planetary roll bite against a thrust of up to 11 tons set up by the rolling action. The pinch and feed roll motors are supplied from a common Ward-Leonard generator.

A slip-ring induction motor drives the planetary rolls continuously at a constant speed, and is controlled by a circuit-breaker and hand-operated liquid starter. To ensure rapid stopping in an emergency, a thruster-operated brake is fitted and is operated by the common emergency stop on the control desks. Another generator supplies Ward-Leonard control of power for the planishing rolls and the two table rolls. The planishing roll motor has a field rheostat to enable its speed to be adjusted to the speed of the strip from the planetary rolls, which is determined by the speed of the feed rolls and the roll setting.

A heavy-duty mill-type motor provides rapid acceleration and retardation for the 3-roll coiler, and is supplied by the third generator. The coiler speed is matched to the outgoing speed of the mill by the use of coupled rheostats in the fields of generators 2 and 3. When the end of a strip has passed between the planishing rolls, the coiler motor speed is increased by 75% so that the strip may be completely coiled, the coil ejected, and the coiler rolls returned to mill speed before the leading edge of the next strip reached the coiler. The two run-out table rolls are adjusted to run at the same speed as the strip from the mill and are not affected by the rapid acceleration of the coiler drive as it coils each strip.

When the mill has been set for a specific programme, the speed of all main drive motors may be varied together over a 2:1 range by controlling the output of the small exciter that supplies the fields of the three generators.

The screwdown motors for the feed rolls and planetary rolls have vertical shafts and are skirt mounted on to the bevel gear units that drive the screwdowns through



Motor-generator set supplying the D.C. driving motors of the mill. Automatic contactor control of the various D.C. drives and A.C. auxiliaries is provided by the control board in the background.

electromagnetic clutches: electromagnetic brakes are also provided. The planishing screwdown motor has a horizontal shaft and drives through a similar arrangement of bevel gears, clutches and brakes. To ensure accurate adjustment during rolling, and the fast separation of the rolls during an emergency, fast and slow operation of the motors is provided with automatic current-limit acceleration on field weakening.

The mill is controlled from three desks set respectively in front of the feed rolls, between the planetary and planishing rolls, and in front of the coiler. All the necessary control switches, pushbuttons, speed regulators and indicating instruments are provided on these control desks.

## Mobile Laboratory for Weld Testing

SPECIALLY designed by Pilgrim Mobile Units, Ltd., of Ringwood, Hants, a mobile radiographic and weld testing laboratory is now in service with Welding Supervision, Ltd., as an addition to their existing fleet.

The new mobile laboratory incorporates spacious dark-room facilities, an office and a testing section. To withstand the rigorous conditions almost invariably encountered on remote sites, a specially strengthened chassis was fitted, and the layout arranged to achieve even distribution of load at all times.

The dark-room is completely light proof and adequately ventilated to permit the welding engineer-radiographers to work under all climatic conditions. A sliding door to the dark-room is fitted with a warning light and automatic lock, as a precaution against interruptions during processing. Two water storage tanks provide a supply of water for the sink, while electrical heating elements maintain the correct temperature for developing chemicals. Acid-resistant plastic splash panels have been used for the wet and dry benches, and the floor, which has good drainage, is surfaced with thick rubber sheeting as a protection against corrosion from chemicals.

The forward compartment of the vehicle is fitted with adequate storage facilities and a work bench, so that welders' test specimens can be ground and filed to the correct dimensions. A fold-away drawing board is available for the welding engineers' technical drawings and sketches, and the X-ray unit can also be stored here.

Mounted over the specially reinforced wheel box is a portable tensile testing and bending machine. The machine, developed by Welding Supervision, Ltd., is capable of pulling test specimens up to 15 tons direct load.

Attractively finished in the Company's colours of maroon and egg-shell blue and roofed with aluminium, the unit carries radioactive isotopes and portable X-ray sets as well as ultrasonic testing equipment. The isotopes, in their containers, are stored in a compartment lined with  $\frac{1}{2}$  in. lead sheet which provides additional screening to the operator, and permits the safe handling of undeveloped films in the workshop and office sections. The unit can also carry magnetic and fluoroscopic apparatus if required.

# Shell Moulding Developments

## Equipment for Core Blowing and Mould Closing

THE technical advantages of the shell-moulding process in the production of small and medium size castings are widely recognised, but the extent of its adoption depends largely on the economic aspect, although there may be cases where the accuracy and surface finish of the castings are considered to be worth the extra cost. It is natural, therefore, that recent developments in this field have taken the form of new machines capable of producing moulds quickly, efficiently and economically.

Some eighteen months ago, Polygram Castings Co., Ltd., introduced their Mark IV shell mould maker, which was a four station machine, and the experience gained with it in various sections of the foundry industry has been invaluable in determining the design of machines to cover an even wider field of application. A number of new developments have recently been introduced, principal among them being a two-station semi-automatic mould maker, a range of core makers, and an adhesive technique for mould assembly.

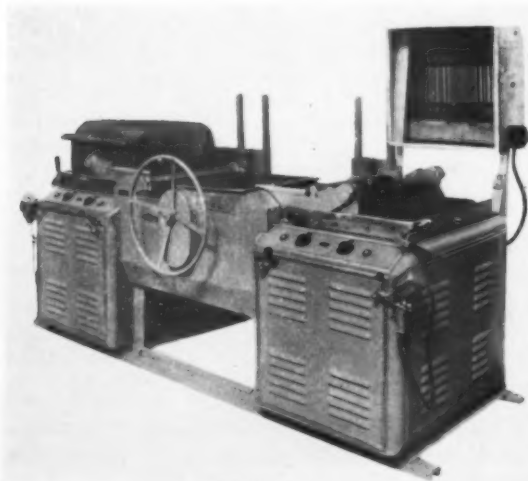
### Two-Station Mould Maker

The two-station semi-automatic mould makers in the Polygram range are fundamentally similar in design, the major difference being in the size of pattern plate which can be accommodated. The Mark V E will handle plates 16 x 12 in. to 20 x 14 in. with a maximum 3-phase 50-cycle power supply of 30 kW, whilst the figures for the Mark VI E are 18 x 14 in. to 24 x 22 in., with a 36 kW power supply, both using compressed air at 80 lb./sq. in. for operation of the machine parts. The Mark VII E, which is to be built later, will accommodate plates between 24 x 20 in. and 36 x 30 in.

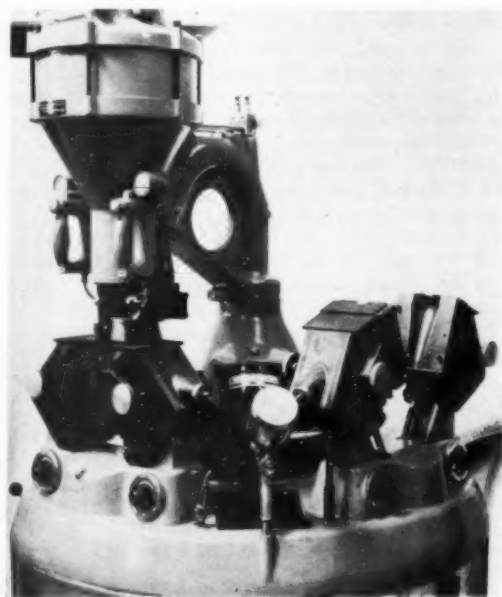
The two electrically-heated curing ovens are at the ends of the machine, with the investment bin in the middle. The patterns are heated by means of the electric

elements in the curing oven: these are situated above the pattern plate within the lifting oven top, and below the plate in a static position. Controlled top and bottom heating ensures even pattern plate temperatures, as each can be separately adjusted to suit the features of the plate. The plate is then sprayed with stripping solution before moving to the dump box by means of the pneumatically operated rollover device. The pattern plate is invested for a pre-determined time by rolling over the dump box by means of the hand wheel in front of the machine. The dump box is then returned to its normal position, and the rollover device is operated to bring back the pattern plate to its original position, with the soft plastic mould adhering to it. The oven is then lowered over the mould for curing, after which the latter is ejected from the pattern by means of the pneumatically operated ejector plate.

Having started the curing operation, the operator then invests the other pattern plate in a similar manner,



Semi-automatic shell mould maker (Mark VI E).



Automatic shell core maker (Mark VIII E).

and by the time that this pattern plate has been invested and returned to the original position for curing, the first mould made is ready for ejection.

The emphasis has been on building machines that will respond to the robust treatment of the sand foundry without loss of efficiency and eliminate the fatigue of manhandling heavy pattern plates. Hence the structure throughout is extremely rigid and the pattern plates are put on and off the dump box pneumatically. The shock of the heavy pattern plate landing on the dump box is prevented by suitable counterbalances which allow the

plates to position themselves gently, and when in position the clamping to the bin is automatic and positive so that no resin/sand mixture escapes to cause uncomfortable working conditions for the operator. All these machines are kept to a minimum overall size by arranging for mould ejection to take place within the area of the electric curing oven instead of on separate tables. Perhaps the most important element of design is the pin method of ejection, without recourse to springs to prevent the pin dropping forward as the pattern plate is inverted. Thus by removing the need for springs the user is no longer concerned by their comparatively short life and the time lost in changing them when they become weakened by heat.



Bench type shell core maker (Mark IX).

#### Core Makers

Owing to the advantages of using shell cores, even in sand moulds and metal dies, the need of a shell core maker was recognised at an early date, but the difficulties to be overcome resulted in the earlier appearance of the mould makers. The advantages of shell cores include a high degree of accuracy, surface finish and permeability, and the elimination of core driers and stoves. Three new machines developed by Polygram have been designed to make a wide range of both complex and simple cores, hollow wherever possible to achieve high permeability and reduced material cost, and yet maintain high strength and good finish.

The Mark VIII E machine is designed for long production runs which do not involve constant changes of core boxes. This core maker consists of a hopper, which holds the investment mixture, and two stations, each of which holds a pair of boxes which are opened and closed pneumatically. The hopper can be rotated through 360° C., so that cores too large to be accommodated at the stations can be made by suitably rotating the head. Removal of surplus material is effected by a combination of blowing and evacuation.

The core boxes are brought to the correct operational temperature by means of the electrical heaters incor-



Jobbing shell core maker (Mark XI).

porated in the grips, and sprayed with stripping solution. The working head is then moved over the core box and clamped into position, and at the press of a button the resin/sand mixture is pneumatically forced into the box. After a five seconds investing period, the surplus mixture is removed, as described above and the working head moved over to the second station whilst curing is completed at the first. Opening and closing of the grips is pneumatically achieved by a simple lever control, and a precise location is automatically assured.

The Mark IX differs essentially from the Mark VIII E in that the fixed jaws have been removed and replaced by three tables, which can be adjusted to suit the varying heights of any three core boxes to be operated in turn. Heating of the mould prior to investment and for subsequent curing is carried out in a separate oven. The main advantage is that many conventional sand foundry core boxes can be used directly without the need of alteration, provided they are made of suitable metal.

The Polygram-Croning Mark XI core maker has been specially designed for jobbing work, and has a great versatility in the number and types of core it can accommodate. The core box is separately heated and, after spraying with stripping solution, is filled by inverting over the blowing head. Depression of a foot pedal admits the resin/sand mixture to the box, where it is held for the investing period. Excess material is emptied over a knock-out grid before returning the box to the oven for curing.

#### Shell Mould Closer

The use of mechanical devices—clips, bolts, etc.—for closing the two halves of shell moulds is time consuming, and suffers from the disadvantage that their action is of necessity localised. A technique developed by Polygram employs hot setting adhesives; the adhesive is applied to a cold half mould, and the heat required to set it is supplied by the other half of the mould which has been heated in a specially designed oven. The temperature to



Shell mould heating oven and vacuum mould closer.

which the top shell is raised is critical, and the oven maintains this temperature  $\pm 10^{\circ}\text{C}$ . It also ensures that a cold shell once placed in the oven cannot be removed until it has reached operational temperature.

In the Polygram mould closer, the completed mould is completely enclosed between two rubber diaphragms, the upper one being mounted on a hinged frame to permit insertion of the mould. When air is exhausted from the space between the diaphragms, a uniform pressure of 15 lb./sq. in. is exerted on both sides of the mould, irrespective of its contours. This pressure is maintained sufficiently long to allow the adhesive to set, after which the top diaphragm is raised and the mould withdrawn ready for casting. The unit is self contained and has an output of some 60 closed moulds an hour.

#### Sand-Resin Mixer

The intimate mixing of the sand and binder is an important factor in the production of satisfactory shell moulds, and a recently developed mixer, besides being efficient, is cheap and simple to operate, and possesses the important merit of being dust proof. It consists essentially of a frame carrying two parallel shafts driven simultaneously by an electric motor through a V-rope reduction train. These shafts carry four rubberised rollers spaced so as to engage a mixing drum, rotating the latter when the motor is started. The drum is fitted internally with a removable agitator assembly, and is closed at one end by a lid with a rubber gasket. Two drums are supplied with each machine, so that one can be emptied and recharged whilst the other is mixing, the agitator assembly being transferred from one to the other.

#### Sand Reclaiming Oven

Although the resin, which is the more expensive component of the moulding mixture, is changed chemically on curing, there are instances when it is worthwhile to save the sand. Investigations into the quality of reclaimed sand have shown that it is not greatly altered by the procedure, and an "incinerator" has been developed for this purpose. This consists of a vertica

cylindrical shell into which pieces of used mould are charged. Ignition is effected by means of a gas torch, but when the pieces are alight the combustion becomes self-supporting, and further pieces can be charged. The usable sand, when free of resin, trickles through the base, and can be collected in a suitable container at a rate of about  $1-1\frac{1}{2}$  cwt./hr.

### A.D.A. Annual General Meeting

THE retiring President, Mr. R. D. Hamer, presided at the recent Annual General Meeting of The Aluminium Development Association, held at 33, Grosvenor Street, London, W.1, and introduced the Report for 1953.

In recording the principal activities of Committees and staff over many and varied subjects, the Report showed good progress with the three-year programme of Research and Development work begun in 1952, with particular emphasis on the structural, marine and electrical engineering fields. During the year, part of the Association's research activities culminated in the publication of no less than nine new Research Reports. There was also a continuation in the trend of educational services with a considerable increase in the use made of them by educational authorities and individual teachers. The demand upon the Association's technical services had increased in practically every direction—for example, over 150,000 copies of new or revised publications were despatched (compared with 131,000 in 1952) and over 430 film shows were given; present library resources include 1,300 literature accessions, over 6,300 photographs and more than 2,000 lantern slides.

The president for the ensuing year, elected at the Annual General Meeting, is Mr. R. T. Priestman, Managing Director of T. J. Priestman, Ltd. Mr. Priestman who has been a member of the Institute of Metals for over thirty years, joined the Council for the A.D.A. in April, 1947, as the representative of ALAR, Ltd. He is a Member of Council (and late Chairman) of ALAR, Ltd., Chairman of its Technical Committee, and a Council Member of the Federation of Light Metal Smelters. The new Vice-President is Mr. R. D. Hamer (Aluminium Laboratories, Ltd.). Mr. Harold Goodwin (Birmetals, Ltd.) was appointed Chairman of the Executive Committee of the Association in succession to Mr. G. W. Lacey.

### Johnson Matthey Telex

JOHNSON, MATTHEY & Co., LTD., have joined the International Telex service, at present providing direct foreign teleprinter communication, and to be extended later this year to include transmissions within the United Kingdom. The system enables messages to be received at any time, and will greatly improve contact with associates, agents and customers. The Company's number is London 8702.

### Fielding Press for Italy

FIELDING & PLATT, LTD., of Gloucester, have recently delivered a 950-ton vertical four-column downstroking flanging press to Officine Meccaniche Ferroviarie Pistoiesi, of Pistoia, Italy. The press will primarily be employed in the production of railway equipment.

SUNVIC CONTROLS, LTD., announced that the telephone number at their Harlow Works has been changed to Harlow 24231/5.

# Post-Graduate Metallurgical Training

## Birmingham Course Now Leads to Master's Degree

THE purpose of the Graduate School of Metallurgy at Birmingham, which has been in existence since 1950, is to provide facilities for study, at an advanced level, of modern developments in metallurgy, and of their application to metallurgical industry. The School is part of a national scheme designed to serve the major industries of the country by providing for the necessary training to be carried out at selected universities.

Quite apart from the benefit to be gained by a renewed study of his specialised interests, the course offers the opportunity for the student to gain a wider view and deeper understanding of his science. An important change which has been made this year is the award of a Master of Science degree to those who already possess a Bachelor's degree, and who satisfactorily complete the course.

### Conditions Governing Entry and Awards

Although nominally of one year's duration, the course is so arranged that the period of full-time attendance at the university is completed in the first nine months of the session, i.e. from early October until the beginning of the following July. During the final three months, each candidate must study and prepare a written account of a suitable metallurgical subject. The account may take the form of a dissertation based on a critical review of the relevant literature, on an experimental research project, or on a case-study in industry.

The normal qualification for entrance is a suitable degree in metallurgy, physics, chemistry or engineering, or an equivalent professional qualification. In general it is expected that entrants will have spent some time, preferably two years or more, in metallurgical industry, but in suitable cases metallurgical graduates with less industrial experience may be admitted.

Subject to a satisfactory performance by the candidate during the session and at the final examinations, on completion of the twelve months course students possessing a Bachelor's degree may qualify for the award of the degree of Master of Science. Students completing the course satisfactorily who have not taken a university degree are awarded the Diploma in Post Graduate Studies (Metallurgy).

### Lecture Courses

The Graduate Course syllabus has been planned to ensure that a student may obtain a broad perspective of modern metallurgical theory and practice but, of the wide range presented, a student may select a number of subjects for study which are most appropriate to his individual needs and background. Normally some 24 topics are chosen from the list of 32.

Five lecture courses are given during the session, each consisting of a number of separate topics. The first course deals principally with factors affecting the structure and economics of metallurgical industry. Students entering the Graduate School will generally have had some introduction to the complex pattern of industry and will be in a better position than the

undergraduate to recognise its importance. The course is designed, therefore, to show how factors such as plant layout, technical process control methods, organisation and management affect the economy of manufacture.

The second and third lecture courses deal with the theory and practice of metallurgical manufacturing processes. In these, emphasis is laid upon the application of modern theoretical knowledge to the manufacturing operations of melting and casting, hot and cold working, and the joining of metals. For example, in the course on melting and casting, applications of thermodynamics to reactions involving molten metals are discussed and, in the case of metal-working operations, recent advances in the theory of deformation processes and of lubrication are considered.

The fourth course is especially concerned with the properties of materials and with techniques of examination. In this course, modern methods for the non-destructive testing of metallic components are considered. Some emphasis is also placed on the applications of X-ray crystallography to metallurgical problems. Many metallurgical phenomena can be understood only in terms of crystallography, and it is likely that X-ray diffraction techniques will play an increasingly important role, both in metallurgical investigations and in routine control work.

The last lecture course takes the form of a review of physical theoretical metallurgy. It should enable the industrial student to understand some of the more recent trends in metallurgical theory, which are now beginning to play an important part in industrial research, and are certain to have important practical consequences in the future. It is significant that the majority of metallurgists now working in industry have not had the opportunity of such a course of study, and feel the lack of it strongly.

### Practical Work

The lecture courses are illustrated and augmented by practical work in the Aitchison Laboratories. These laboratories are equipped with representative examples of full-scale manufacturing plant used in a wide range of casting and metal working operations. Modern equipment for mechanical and non-destructive testing, metallography and X-ray crystallography is also available. In their practical work, students may study the application of the scientific principles discussed in lectures to investigations and development work under the conditions of practical production. Where possible, work of this type is supplemented by selected visits to metallurgical works using advanced techniques of manufacture.

### Other Activities

Graduate students are required to take part regularly in seminars. Each student during the course of a session gives two or three papers on a subject broadly related to the field of industrial metallurgy. Each paper is followed by an informal discussion amongst the post-graduate and honours students present. The seminar

system is excellent for teaching the graduate student to make a survey of the available knowledge on a subject, to select the important and relevant data and, finally, to present an account in a suitable and concise manner.

In addition to the specific aspects of the course mentioned above there is the less tangible but important aspect that, during their full-time course, graduate students have the opportunity of taking a full share in university life. Provision has been made for some of the students to live in a hostel established by the

University at Chad Hill, where students from the other Graduate Schools. (Mechanical and Chemical Engineering and Engineering Production), and also research students from other departments will be in residence.

#### Information and Registration

Forms of application may be obtained from the Registrar, The University, Edgbaston, Birmingham, 15, and further information about the course from the Department of Industrial Metallurgy.

## Z.A.D.C.A. Annual General Meeting Certification Scheme and O.E.E.C. Mission Discussed

**A**T the luncheon which preceded the recent Annual General Meeting of the Zinc Alloy Die Casters' Association, Mr. H. A. R. Binney, Director of the British Standards Institution spoke on the new certification scheme for zinc alloy die castings.

He said the industry was fortunate in being allied to trades which were expanding. It was an excellent example of high quantity production, needing close production control, which brought its own problems. As a result of the anxiety of substantial interests in the industry to maintain the high reputation it had already achieved, representatives of the industry and of the British Standards Institution had joined together in producing a Certification Scheme under which a purchaser could be sure that he would be satisfied with products made under controlled conditions and independently inspected by the B.S.I. In most spheres of industry there could be a small section who would forsake good standards for the temporary advantage of lower price, with the attendant danger of bringing censure, not on a particular manufacturer or trader, but on the trade as a whole.

Mr. Binney emphasized the importance of all reputable manufacturers joining the scheme, to ensure that none of the small minority should be able to say that they were in the same position as certain responsible people who were not in the scheme. Similar schemes were operating in such fields as the building and electrical industries, where both buyers and sellers had grown to realise the value of this independent certification. There were, to-day, nearly 90 schemes operating, including nearly 1,200 manufacturers, which was twice as many as two or three years ago. Z.A.D.C.A. had shown a high sense of responsibility, and a determination to ensure continuation of the good name associated with their products.

#### O.E.E.C. Die Casting Mission

At the meeting of Z.A.D.C.A. after the luncheon, some observations were made by British members of the O.E.E.C. Mission on Zinc and Light Metal Die Castings who had very recently returned from the United States. The secretary of the Mission, Mr. A. R. L. Chivers, of the Zinc Development Association, described the arrangements that were made for the Mission's visits to American die casting foundries, machine makers, and other firms interested in pressure die casting. The Mission consisted of 31 people from 11 European countries and was divided into four groups, each with a special interest. The first

group studied die casting machines and die production; the second, the metallurgy, manufacture and control of the alloys used; the third foundry practice; and the fourth group, the finishing and end uses of die castings. The last three groups were led respectively by Mr. B. Walters, of the Imperial Smelting Corporation, Ltd.; Mr. F. C. Claxton, director of the Wolverhampton Die Casting Co., Ltd. and Mr. A. P. Fenn of the Birmingham Aluminium Casting Co. (1903), Ltd.

In replies to questions to members of the Team, the following points emerged: A number of American die casting firms are using non-inflammable hydraulic fluids in their machines. They are still not perfect, all the fluids being highly detergent, thus necessitating frequent filtering and the use of special packings. Most of the foundries visited which are considered small by American standards, though hardly comparable with small firms in Europe, employ comparatively large machines of at least 300 tons locking pressure, and make a wide range of products, but most of the orders are for much longer runs than are needed in Europe, so that the machines can be worked semi-automatically. The machines work faster, a machine of 400 tons locking pressure commonly operating at 400 shots an hour. As far as possible mechanisation is used in the subsequent trimming and polishing processes.

American wages are equivalent to 12s. an hour for machine operators, and about £1 an hour for skilled die makers. The quality of American die castings varied considerably, from some of the very highest standard to others that no British die caster would be proud of. Probably about 25% of the castings were of superior quality to those found in Europe, the high quality being apparently due to the special care devoted to die construction, the use of very thorough water cooling, and to semi-automatic machines ensuring that the dies always operate under optimum conditions. In America, as in Europe, the motor car industry is the largest consumer of zinc alloy die castings, but home appliances—covering all kinds of products from tin openers to refrigerators—are the next most important use. The American die casters were all sure that their high rate of output would be maintained and increased in the future. Although aluminium was threatening some zinc uses, die casters were very active in pursuing new applications for zinc alloy die castings. The Team members were confident from what they saw that the American industry would continue to expand.



**"I'm getting cold feet,"** *fumed the Fire Walker*

"I shan't have a leg to stand on if I can't find something better than this. What I need in my job is a *high* temperature and a *constant* temperature. I'll

go West and see Shell-Mex and B.P. Ltd. If oil fuel and their advice on how to use it can't solve my problem, nothing can!"

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# NEWS AND ANNOUNCEMENTS

## Magnesium Industry Council

THE Magnesium Advisory Committee which was formed early in 1952 has now been reconstituted as the Magnesium Industry Council. The Council will continue the activities of the Committee as a consultative and advisory body, and has extended its scope through the formation of panels of technical and commercial experts. The purpose of the Council is to promote the production and use of magnesium and its alloys. The services of the Council are available to industry and to the ministries responsible for the defence programme.

The present Members of the Council are: Aeroplane & Motor Aluminium Castings, Ltd.; Birmetals, Ltd.; Birmingham Aluminium Casting (1903) Co., Ltd.; James Booth & Co., Ltd.; High Duty Alloys, Ltd.; International Alloys, Ltd.; Kent Alloys, Ltd.; Magnesium Castings & Products, Ltd.; Magnesium Elektron, Ltd.; Rolls Royce, Ltd.; Sterling Metals, Ltd.; J. Stone & Co. (Charlton), Ltd.; Stone-Fry Magnesium, Ltd.; and T. I. Aluminium, Ltd.

The Chairman is Mr. E. Player, Birmid Industries, Ltd., and the Secretaries, Wenham Brothers & Co., 21, Bennett's Hill, Birmingham, to whom enquiries should in the first place be addressed.

## Research Assistantships

APPLICATIONS are invited for full-time Research Assistantships in a number of Departments, including that of Metallurgy, at the Sir John Cass College. The purpose of the awards is to enable students who are suitably qualified to obtain training at the College in methods of research under the supervision of the Head of the Department. Normally, Research Assistants will proceed to a higher degree of the University of London.

The Assistantships are tenable for two years and may be extended for a third. The value is £350 per annum which is, at present, subject to income tax and national insurance contribution deductions. Holders of the award will be required to undertake teaching duties for six hours weekly without further payment.

Application for an award, tenable from September 1st, 1954, is to be made on a form obtainable from the Secretary of the College, Jewry Street, Aldgate, E.C.3.

## Lackenby Works Mills Drive

METROPOLITAN-VICKERS ELECTRICAL CO., LTD., has received an order, worth over £750,000, for three mill drives for the Lackenby Works of Dorman Long & Co., Ltd., comprising a 40-in. roughing mill, a 53 in. universal beam roughing mill, and a 53-in. universal beam finishing mill. It is hoped that the new mills will be operating and producing universal beams in September, 1956. To ensure this programme being kept there will be the closest collaboration between Metropolitan-Vickers and its associates, The British Thomson-Houston Co., Ltd. The two companies will share in both the design and manufacture of this equipment, which will be built in their respective Works at Trafford Park and Rugby. Each of the three mills will have as a main drive a double-armature main motor of 24,000 h.p. peak, and in addition the beam roughing and finishing mills will each have

a supplementary stand powered by a twin drive rated at 8,100 h.p. peak.

## Perchloric Acid in Analysis

ORGANISED by the Society for Analytical Chemistry, a special meeting to discuss the use of perchloric acid in analytical chemistry will be held in the Lecture Theatre of the Royal Institution, 21, Albemarle Street, London, W.1, at 6 p.m. on Wednesday, July 21st, 1954. Professor H. Burton and Dr. P. F. G. Prall (Queen Elizabeth College, University of London), will present a paper on "Perchloric Acid and Some Organic Perchlorates," and Prof. G. F. Smith (University of Illinois) is making a special journey from the U.S.A. to lecture on "A Bomb in a Test Tube. Perchloric Acid Idiosyncrasies." The authors of these papers have made a special study of the properties of perchloric acid, and will give the meeting the benefit of their experience to show how the reagent can be used safely.

## Profiloscope Distributors

RUDKIN & RILEY, LTD., of Aylestone, Leicester, manufacturers of the "R. & R." range of die shop equipment, have been appointed sole distributors to the wire industry, both at home and overseas, of the wire drawing die profiloscopes manufactured by The Longworth Scientific Instrument Co., Ltd. and designed by The British Iron and Steel Research Association.

## Laboratory Furnishers' Merger

It is announced that a new company, Griffin & George, Ltd., has been formed by the merging of Griffin & Tatlock, Ltd., and W. & J. George & Becker, Ltd. The joint statement issued by the Directors of the two firms indicates that, pending the administrative and physical integration of the two organisations, which will be a gradual process, they will continue to trade under the existing names, and at the present addresses.

## Telephone Change

THE telephone number of the Federation of Light Metal Smelters, 16, Coleman Street, London, E.C.2, has been changed from Royal 1291 to Monarch 9988.

## Personal News

MR. R. WILLIS and Mr. P. E. H. WILDE have been appointed Directors of the Sheffield Forge and Rolling Mills Co., Ltd., the newly acquired company of the Darwins Group. Both are directors of Darwins, Ltd., Mr. Willis being Works Director and Mr. Wilde Sales Director.

MR. J. M. RIDGION has been appointed Deputy Head of B.I.S.R.A.'s Ironmaking Division and Head of the Association's North East Coast Laboratories at Normanby, near Middlesbrough. Mr. Ridgion has been engaged on co-operative research work in the iron and steel industry since 1936, when he joined the Technical Department of the British Iron and Steel Federation and worked under B.I.S.R.A.'s predecessor, the Iron and Steel Industrial Research Council.

Mr. M. N. BOYDE, previously Publicity Manager at Foundry Services, Ltd., has now joined Polygram Casting Co., Ltd., as Sales Manager covering the sale of Polygram shell moulding machines and equipment.

SIR GEORGE H. NELSON, Chairman of the English Electric Group, has just completed a 20,000-mile tour of Central and South America and the Caribbean area, where he has been during the past 14 weeks.

MR. A. E. GRIMSDALE, Special Assistant Sales Management, Metropolitan-Vickers Electrical Co., Ltd., has been appointed a Director of Metropolitan-Vickers Electrical Export Co., Ltd.

McKECHNIE BROS., LTD., announce the appointment of Mr. G. C. WALTON as Sales Manager. Mr. Walton has been Manager of the Newcastle-on-Tyne Branch of the Company for many years.

THE President of the Board of Trade has reappointed SIR PERCY H. MILLS, Bt., K.B.E., as Chairman of the National Research Development Corporation for a further period. PROF. P. M. S. BLACKETT, F.R.S., SIR JOHN DUNCANSON and SIR EDWARD DE STEIN have also been reappointed as members. SIR HENRY HINCHCLIFFE, D.L., J.P., and SIR ALAN SAUNDERS, O.B.E., have been appointed in place of the retiring members, SIR EDWARD HODGSON, K.B.E., C.B., and Mr. W. E. P. JOHNSON, A.F.C.

MR. I. A. MARRIOTT has been elected to the Board of Wellworthy, Ltd., piston and piston ring manufacturers. Mr. Marriott had previously been, since the war, with the Brush Group as Group Commercial Director. He later became Managing Director of W. G. Bagnall, Ltd., of Stafford, and of the Parsons Engineering Company of Southampton.

BRITISH INSULATED CABLES, LTD., announce that Mr. J. S. MAKIN has been appointed Branch Manager of their Manchester Office.

THE President of the Board of Trade has approved the appointment of Mr. J. L. GIRLING, a Superintending Examiner in the Patent Office, as Comptroller-General of Patents, Trade Marks and Designs in place of the late Sir John Blake.

MR. R. E. BUELL has been appointed Controller of the Technical Division of the Regent Oil Co., Ltd. He comes to Regent from the Caltex Research and Development Division, New York, where he has been the Supervisor of the Products Section for the California Texas Oil Company.

MR. S. RYMELL, who was for many years Deputy Chief Inspector with Westland Aircraft, Ltd., has been appointed to a similar position with Folland Aircraft, Ltd.

WICKMAN, LTD., announce that Mr. G. R. MARSH, who has been a Director of the Company for 14 years, has now been appointed Managing Director.

MR. H. T. WORDSWORTH has resigned from the Board of Sanderson Brothers and Newbould, Ltd., on the grounds of ill-health. Mr. Wordsworth has served the Company for 56 years and has been a Director since 1931. Mr. J. LONSDALE, Works Manager, has been appointed to the Board.

MR. G. U. NODEN, has resigned his position as Works Director with Low Moor Alloy Steelworks Ltd., and as Alternate Director to Yorkshire Rolling Mills, Ltd.

## Obituary

### Mr. T. Makemson, M.B.E.

THE sad news of the death of Tom Makemson, as he was affectionately known, would come as a great shock to many readers of this journal. During his 27 years' service as Secretary to the Institute of British Foundrymen he has helped, in no small measure, to build up that Institute from a membership of about 1,600 to one of well over 5,000, with greatly increased activities and interests. In addition, he was for 21 years part-time Secretary of the Manchester Association of Engineers.

Born at Workington, Cumberland, in 1890, he served an apprenticeship as a patternmaker, on completion of which he moved to Manchester and worked as a patternmaker for the firm then known as the British Westinghouse Company, now Metropolitan-Vickers Electrical Co., Ltd. His patternmaking experience gave him a special interest in the foundry, and he took a five-year part-time course in metallurgy at the Manchester College of Technology and gained the Associateship of the College, in addition to a first-class certificate in iron and steel manufacture and several other certificates in engineering subjects. Besides working as a patternmaker, he took over the teaching of foundry and patternshop apprentices in the British Westinghouse works school. This led to full-time work in the education department of that Company, which had then become Metropolitan-Vickers Electrical Company, and eventually he was transferred to the research department.

Early in 1922 he was elected Honorary Secretary of the Lancashire Branch of the Institute of British Foundrymen, and near the end of 1926 he was appointed Secretary of the Institute. In addition he was Honorary Secretary of the International Committee of Foundry Technical Associations at the inaugural meeting held in Brussels in December, 1926, and still held that post at the time of his death. His other activities included the Secretaryship of the Advisory Committee on Examinations in Patternmaking and Foundry Practice of the City and Guilds of London Institute and, for many years, membership of the Council of the British Cast Iron Research Association.

During the last war he was seconded by the Institute of British Foundrymen to the Iron and Steel Control of the Ministry of Supply, being successively Deputy Director, Joint Director and Director of Iron Castings. For his services he was created a Member of the Order of the British Empire, and the Institute of British Foundrymen awarded him the E. J. Fox Medal.

Tom Makemson had the difficult task of guiding the Institute of British Foundrymen through its most difficult period; during the last war the task of helping the ironfounding industry to organise for war output was both difficult and delicate; when it was over the task of guiding restoration to normal conditions and encouraging expansion was more congenial, but in each case talents of a high order were necessary and the great success he achieved can be regarded as a measure of the talents he possessed and used for the advancement of the foundry industry.

In addition to great ability he had a charming personality, which endeared him to all with whom he came into contact, and a host of friends, both in this country and abroad, will regret the passing of so worthy a man at the relatively early age of 64. C.A.O.

# RECENT DEVELOPMENTS

## MATERIALS : PROCESSES : EQUIPMENT

### Univector Polarograph Unit

THE CAMBRIDGE INSTRUMENT CO., LTD., have developed an attachment for use with their pen writing polarograph, which enables a pure A.C. voltage to be superimposed on the standard D.C. voltage applied to the Heyrovsky mercury dropping system. This produces polarograms that are of greater sensitivity and simpler to resolve than the ordinary step polarogram.

With the Cambridge Univector attachment, the polarograms reproduced are automatically analysed and phase selected so that the records produced are of a simple form, and require only one linear measurement to determine the concentration of the element under test. The record pattern does not follow the customary step formation but rises from the base line to a height that is a direct linear function of the concentration of the element, after which it returns to the base line which is always at zero current.

The sensitivity of a polarogram, when using the Univector unit, may be as great as 20 times that of a standard step polarogram, enabling detection of many substances to be made down to concentrations of 0.1 mg/litre. Concentrations of 1 mg/litre can be determined with an accuracy of 5% and concentrations of 10 mg/litre can be dealt with in ordinary routine measurements, as compared with the 100 mg/litre concentration that is usual in step polarography. The measurements are less affected by dissolved oxygen, thus saving time in gas purging.

Among other advantages of the Univector method is the fact that the sensitivity of the reaction depends upon the nature of the electrolyte but not normally upon its concentration, so that substances having close reduction potentials can be adequately separated by using a correctly selected electrolyte. This also assists the measurement of alloy constituents which can be determined without prior chemical separation. As an example it is possible to measure 0.2% cadmium in copper without chemical separation.

*Cambridge Instrument Co., Ltd., 13, Grosvenor Place, London, S.W.1.*

### Cold Pressure Welding Tool

A NEW cold pressure welding tool recently produced by G.P.A. Tools and Gauges, Ltd., is intended for butt-welding wires, particularly of aluminium and copper, from 0.036 in. to 0.064 in. in diameter. It is a recent addition to the range of equipment made by The General Electric Co., Ltd. for cold pressure welding. With this technique, which was developed at the G.E.C. Research Laboratories, aluminium and copper wires can be welded by pressure alone, no heat being required; the joints obtained have a mechanical strength and an electrical conductivity equivalent to those of the parent wire. Certain aluminium alloys such as Silmalec can also be welded in this way. The technique was developed as a convenient method of joining aluminium conductors which are now being used on an increasing scale. A larger model covers the welding of wires from 0.080 to 0.144 in.



Operation is simple and can be carried out by an unskilled operator. The wires are inserted into split tapering jaws and gripped tightly. Next the ends are cut square by a cutting mechanism incorporated in the tool. Then the cutter is swung clear and the wires are brought hard up together, with sufficient pressure to effect a weld. Part of the metal is displaced sideways, forming a flash which can be trimmed in any manner that may be convenient. No flux, chemical or gas is required in the process.

*The General Electric Co., Ltd., Magnet House, Kingsway, London, W.C.2.*

### Automatic Welding Blowpipe

WITH the conventional blowpipe, the correct flame, neutral, oxidizing or reducing, is obtained by the operator setting the recommended pressure readings on the outlet gauges of both oxygen and acetylene regulators and then manipulating the blowpipe valves.

During the progress of welding operations it is frequently necessary, because of positioning or adjustment of the work piece, to withdraw the blowpipe flame, possibly only for a minute or so, during which time valuable gases are needlessly burned to waste. Alternatively the gases may be shut off and much time is lost in consequent blowpipe flame re-adjustment.

The B.I.G. Automatic welding blowpipe is designed to eliminate this wastage of time and gases. The blowpipe retains all the characteristics of the well-known range of B.I.G. welding blowpipes, and is operated in exactly the same manner when once the original flame adjustment has been made. The operator controls his supply of oxygen and dissolved acetylene simply by moving the thumb control backwards and forwards. The forward movement brings the full welding flame on while the backward

movement shuts it off, leaving only a tiny pilot light. The Automatic is available in two sizes: Model 16 for welding up to  $\frac{1}{4}$  in. mild steel plate; and Model 17 for heavier sections. The standard range of welding tips, series 1390, are suitable for use with both models.

*British Industrial Gases, Ltd., 32, Victoria Street, London, S.W.1.*

### **"Kodak" X-Ray Processing Unit Model 56**

THE "Kodak" X-ray Processing Unit Model 56 is a 5-gallon model designed especially for the medium-sized X-ray department. It comprises a developing tank, rinse compartment, two fixing tanks and a wash compartment, and films can be processed at a rate of 60 per hour. Multiples of the unit are suitable for larger X-ray departments. The unit, which has an outer shell of resin-bonded plywood, has external panelling, and is finished internally with black "Phenoglaze" paint. All corners and edges are capped with polished stainless steel, and the whole unit is extremely easy to keep clean.

The three 5-gallon tanks, one for developer (provided with a plastic cover) and two for fixer, will each take six film hangers of a size up to and including  $14 \times 17$  in. The rinse compartment, which divides the developing tank from the fixing tanks, has a spray rinse controlled by a valve mounted in the front recess, but a running rinse can be supplied if preferred. The tanks are contained in a water-jacket compartment, which holds  $17\frac{1}{2}$  gallons of water, and which is heated by a 600-watt Aidas immersion heater. A Cambridge dial thermometer, in conjunction with a Sunvic hot-wire relay controls the temperature of the water, and the heater is automatically cut out if the water falls below a safe level. The wash compartment which forms an integral part of this unit will house 24 film hangers together with a "Kodak" No. 173 Processing Tank (supplied, as an accessory, for wetting agent if required).

All the pipework, instruments, valves and electrical connections are located in the front of the unit for easy maintenance. The front panel can be removed quickly, so that servicing can be carried out without disturbing the unit as a whole. The pipework is so arranged that it can be connected to the "Kodak" X-ray Washer Model 112 if required. The unit can be supplied either for left-to-right or right-to-left working.

*Kodak, Ltd., Harrow, Middlesex.*

### **New Lead Sulphide Photocell**

THE new Mullard photocell, the 61SV, is of the photoconductive lead sulphide type, and is characterised by extreme sensitivity to infra-red radiations and an unusually high speed of response. It has the additional advantages of a high signal-to-noise ratio, small size and robustness. These features make the new cell of considerable value for applications in a large number of industries and branches of research. For example, it makes possible notable advances in radiation pyrometry, enabling very small temperature variations to be detected in low temperature sources down to  $100^{\circ}\text{C}$ . This means that the 61SV cell can be used for such typical applications as controlling and monitoring the work in radio-frequency heating, and in similar industrial setups where the detection of temperature or temperature

changes without actual contact with the work is required. It is likewise of use for measuring the temperature resulting from severe braking in wheels on railway carriages, for detecting hot axle bearings, and in a number of industrial control and protective systems where the exclusion of visible light necessitates the use of invisible, infra-red radiations. A further and very important extension in this field of application is the monitoring of gas, oil-fired and pulverised fuel furnaces, when the cell is used to follow the temperature fluctuations rather than the luminosity of the flame.

In these applications there is no physical contact between the detecting instrument and the source under investigation, and the new cell is, in fact, capable of detecting the heat radiations from relatively low temperature sources situated at distances of 100 yards or more away. This is a feature of considerable significance in a large number of industrial processes, as temperature detection and control of low temperature sources can be effected on work which is moving at high speeds on production lines and in industrial processes. Temperature measurement on this class of work, i.e., below  $700^{\circ}\text{C}$ ., has previously been extremely difficult to achieve. Other important applications of the 61SV lead sulphide cell include intruder or burglar alarms, infra-red telephony, and industrial and astronomical spectroscopy. It also opens up possibilities for the rapid measurement of humidity and for gas analysis.

*Mullard, Ltd., Century House, Shaftesbury Avenue, London, W.C.2.*

### **Photographic Drying Cabinet**

THE Kodak Drying Cabinet (Model B) has been specially designed for all those who need a compact drying cabinet suitable for small numbers of miniature films, roll films, sheet films, plates and X-ray films. Weighing only 45 lb., it is rectangular and stands conveniently on a bench in the workroom: the finish is hammered grey stove enamel.

A slot round the top of the cabinet forms an air inlet, and a small electric fan, mounted at the top of the cabinet over a cylindrical 800-watt heater, sends a stream of warm air through the cabinet. The fan is silent in operation and a small red lamp on the front of the cabinet indicates when it is switched on. The fan motor units are normally supplied to run on either 100/115, 200/220 or 230/250 volts, 50 cycles A.C. A D.C. fan motor unit is available to special order only. Access to the fan motor unit can be made by removing the top plate of the cabinet, which is held in position by four screws.

A wire grille is fitted beneath the heating unit, and directly beneath this, two slotted angle plates are fitted which will take ten special stainless-steel rods. Roll films and miniature films can be hung from these rods by means of film clips and weight rings, or a standard Kodak film draining rack, to hold 13 films, can be attached to the back of the cabinet.

An open wire shelf, also available as an accessory, can be fitted on adjustable bracket supports at a suitable height to take Kodak sheet film and plate processing racks. Additional racks will stand on the open wire floor of the cabinet, and a considerable number of sheet films and/or plates can be dried at one time in these racks.

*Kodak, Ltd., Harrow, Middlesex.*

# CURRENT LITERATURE

## IDEAL FOUNDRY IN PICTURES

64 pp., 10½ x 8½ in., numerous illustrations. Published by The Organisation for European Economic Co-operation and obtainable from H.M. Stationery Office. 8s. 6d.

THIS is a survey based on the experience of a European Mission organised in 1952 under the auspices of the O.E.E.C. and Mutual Security Agency to enable a group of industrialists to attend the International Foundry Congress at Atlantic City, and to visit a number of foundries in the United States. It was difficult to draw up a complete report on a visit of relatively short duration, the main feature of which was a Congress which has already been fully reported. Moreover, several excellent reports on the foundry industry in the United States had already been published, and it was felt that it was unnecessary to cover the same ground again. It was decided, therefore, that a "visual" document, based on a short report by Mr. Romagnoli Mosca, would be more appropriate.

The report is a well illustrated summary of the points which impressed the experts most, and which together provide a series of examples which may help foundrymen to improve their plant and methods. It is hoped that this document, which has more the character of a propaganda pamphlet than a report, will be given the widest possible circulation throughout the foundry industry, so as to reach not only heads of firms but engineers, foremen and workers as well.

A feature of the illustrations is the clean light appearance of the works shown, and although much of the equipment employed in the United States cannot readily be used in most European plants because it is too big—and too costly—it was thought that pictures of such equipment might suggest less costly adaptations and systems, or semi-automatic instead of fully automatic installations. This possibility is mentioned in a number of cases, while in others the reader has been left to draw his own conclusions from the text and photographs.

## INDUSTRIAL DIAMOND TRADE NAMES INDEX

Fifth Edition, 1954. Compiled jointly by Industrial Diamond Information Bureau and Industrial Diamond Review, 124 pp., 8½ x 5½ in. N.A.G. Press, Ltd., 226, Latymer Court, London, W.6. 3s. 6d.

THIS Trade Names Index, first published in 1945, has been thoroughly revised and now contains about 2,500 trade names. A data sheet supplement gives information on a number of subjects to users and producers of diamond tools, and the physical and chemical properties of diamond, the crystallography of diamond and the care of diamond truing tools, shaped diamond tools, and glaziers diamonds, are covered. Further, a list of diamond tool standards as established in Britain and other countries is given as well as a comparison of fine sieve sizes. The Trade Names Index not only contains registered trade names, but also generally-used abbreviations and names of firms which have a special standing in the trade. A classified index covering over 20 individual groups is added so that trade names which are used in any particular branch of the industries using and working hard materials can easily be found.

## Trade Publications

ALTHOUGH beryllium is a relatively expensive metal, the effect of small quantities on the properties of a number of alloys have led to its use as an alloying addition, particularly in beryllium copper and in certain light alloys. Some aspects of its use in the latter group of alloys are discussed in a leaflet entitled "Beryllium in Light Metal Alloys," published by The Beryllium Corporation (U.S.A.). Reference is made to three master alloys: beryllium-aluminium; beryllium-aluminium-magnesium; and beryllium-magnesium. Beryllium-copper master alloys can also be used in the production of certain light alloys. Copies of the leaflet may be obtained from Beryllium Smelting Co., Ltd., 36-38, Southampton Street, London, W.C.2.

A NEW design of hydraulic lip-axis tilting furnace for metal melting is described in a leaflet issued by Monometer Manufacturing Co., Ltd. 115-116, Strand, London, W.C.2. It is made to take standard crucibles, or it can be fitted with a cast iron pot for melting zinc-base alloys, white metals or lead. An interesting feature of the furnace is that the hydraulic equipment is mounted alongside the furnace and not in a pit, thus eliminating difficulties due to metal spillage and the collection of dust and water in the pit.

THE increasing interest in the rare earth metals, and the widening range of their industrial applications, has prompted British Flint and Cerium Manufacturers, Ltd., to compile brief notes on the properties of cerium and its alloys, and copies of a pamphlet which incorporates this information can be obtained from the Company at Tonbridge, Kent. In the section on uses of cerium *mischmetall*, reference is made to lighting aids (flints), electronics, heating element alloys, nodular cast iron, steels, magnesium alloys and aluminium alloys.

As was announced recently, High Duty Alloys, Ltd., Slough, have acquired sheet and plate rolling facilities in South Wales and a new booklet issued by the Company gives technical data on Hiduminium products in this field. Following a brief outline of the scope of the plant, advice is given on selection of alloy and temper, storage and fabrication. The greater part of the publication deals with size limits and the mechanical properties of the various Hiduminium alloys in sheet and plate form. Tables for use in connection with this class of product complete the contents.

THE widespread industrial use on a large scale of X-ray and radioactive isotope radiography has led to a demand for darkroom equipment that will simplify the operator's work and help to produce first-class radiographs. A recent publication of Kodak, Ltd., lists the available darkroom accessories marketed by the Company. Such items as processing units, drying cabinets, illuminators, etc., are described in separate leaflets, the present one dealing with film clips and hangers; wet film accessories; mixing plungers to enable solutions to be mixed in the tanks; thermometers; and safelights.

BOOK No. 112, recently issued by Foster Instrument Co., Ltd., Letchworth, is a 70-page publication dealing with

pyrometers of the thermo-electric type. A seven-page section deals with the theory of this method of measurement, and with some of the practical problems involved. This is followed by detailed and illustrated descriptions of the types of thermocouple made by the Company, and of the indicating, recording and checking instruments for use with them.

A FOUR page leaflet available from The Power-Gas Corporation, Ltd., and Ashmore, Benson, Pease & Co., Parkfield Works, Stockton-on-Tees, will be of interest to those sections of the engineering industry which find that the maintenance of a permanent radiographic department would not be an economic proposition. It describes a self-contained radiographic unit which, with fully-qualified staff, is available for hire and able to travel to any site for the critical examination of welded vessels, pipework, structures, etc., in the field, to such standards as Lloyds Class I, Admiralty Grade A, A.O.T.C. and the A.P.I.—A.S.M.E. Code.

LEAFLET M.E.6 of Sanderson Brothers and Newbould, Ltd., Sheffield, outlines the general range of the Company's products including high speed and tool steels, engineering constructional steels, tools of many kinds, and certain specialised engineering components. Further details of the high speed steel tool bits, including lathe, boring and planing tools, can be obtained from leaflet H.7, whilst hacksaw blades for hand and machine use, and in high speed and tungsten steels are described in M.E.11.

A publication describing the operation of the S.E.I. electro-magnetic transducer system has recently been issued by Salford Electrical Instruments, Ltd. The system, which enables a reading to be taken at a distance of up to 1,000 yards from the point at which the actual measurement is made, is highly versatile. It is used in the aircraft industry, in asbestos sheet manufacture, in plastics production, in rolling mills and in coal bunkers, as well as for many other applications. The new publication includes a general description, describes the standard heads and indicating instruments used with this system, and shows six typical applications in diagrammatic form; a full technical specification is also included.

THREE brochures issued recently by Davy and United Engineering Co., Ltd., serve to correct any impression that may exist that the Company's sole activity is the manufacture of heavy plant for the metal working and other industries. The brochures cover iron castings, steel castings and heavy weldments, all of which can be supplied to customers' requirements. These activities are, of course, related to the Company's main business as they are all used in heavy plant production. Iron castings from a few pounds up to 60 tons in weight can be made in grey iron or spheroidal graphite iron. The steel foundry which has been established 40 years, has facilities for making castings up to 12 tons finished weight for general, steelworks and marine engineering. As might be expected from a knowledge of the firm's products, the facilities for fabrication are extensive and weldments up to 50 tons individual weight can be produced. All the brochures are profusely illustrated with views of the facilities and products of the respective departments.

RUDKIN & RILEY, LTD., of Aylestone, Leicester, have recently completed a consolidated brochure

presenting a general picture of the Company's range of equipment, developed over a number of years in an effort to provide the increased production and improved die finishes called for by the wire drawing and allied industries. The "R & R" die shop service provides a complete range of accessories and modern machines for the preparation and maintenance of all types of drawing and extrusion dies.

Two new leaflets about aluminium paint have been issued by Northern Aluminium Co., Ltd., Banbury. The four-page folder "New Developments" introduces two important new grades of Noral Alpaste—"Standard Polished" and "Standard Naphtha"—and also lists the revised names that have recently been given to the various grades, with notes on typical uses and a complete table of properties. Of the new grades, Standard Polished satisfies the demand for an aluminium paste capable of producing a much brighter paint than the normal Standard grade while having the same durability. Whilst Standard Naphtha is offered specially for use with modern synthetic paint vehicles not based on white spirit solvents. The other folder, "What You Want to Know about Aluminium Paint," is intended to tell the paint user about the nature and properties of paint made from Noral Alpaste. It briefly describes the paint's unconventional structure, to which it owes its excellent resistance and hiding power, mentions the different sorts of aluminium paint available, and outlines their characteristics and the best method of applying them to all types of surfaces.

In a 32-page illustrated booklet, Metallisation, Ltd., of Dudley, pose a number of questions likely to be asked by potential users of the metal spraying process, and give the answers. Besides manufacturing equipment for carrying out the process, Metallisation have what is claimed to be the largest contracting metal spraying works in the world. The questionnaire covers such aspects as metals, machines, coating thickness and quality, painting, preparation and building up. The booklet concludes with a four page outline of the theory of metal spraying for those anxious to gain a more intimate knowledge of its use.

## Books Received

"The Structure of Metals and Alloys." Institute of Metals Monograph and Report Series No. 1. 3rd edition. By Dr. William Hume-Rothery, O.B.E., F.R.S., and Professor G. V. Raynor, D.Sc. 363 pp. inc. numerous illustrations and name and subject indexes. London, 1954. The Institute of Metals. 35s. (\$5.50).

"Ferrous Process Metallurgy." By John L. Bray (Late Professor of Metallurgical Engineering, Purdue University). 414 pp., inc. numerous illustrations and index. New York and London, 1954. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 52s. net.

"Induction and Dielectric Heating." By J. Wesley Cable. 576 pp., inc. numerous illustrations and index. New York, 1954. Reinhold Publishing Corporation. In this country: Chapman & Hall, Ltd. 100s. net.

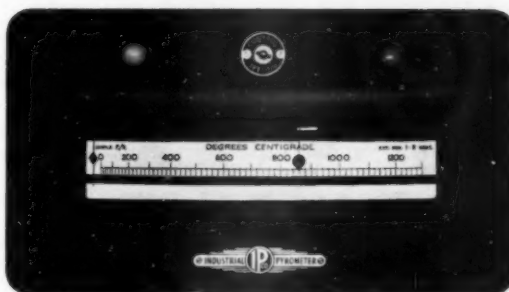
"Deep Drawing." (A Review of the Practical Aspects of Professor H. W. Swift's Researches). By J. Willis. 134 pp., inc. numerous illustrations. London, 1954. Butterworths Scientific Publications. 25s. net. By post 8d. extra.



## PYROMETERS for INDUSTRY

This advanced controller has achieved outstanding success by its simplified mechanism, which ensures high accuracy, close temperature control and consistently high performance.

Also available in "HEAVY DUTY," "MINIATURE" and "RECORDING" Models. For further information write for list No. 525.



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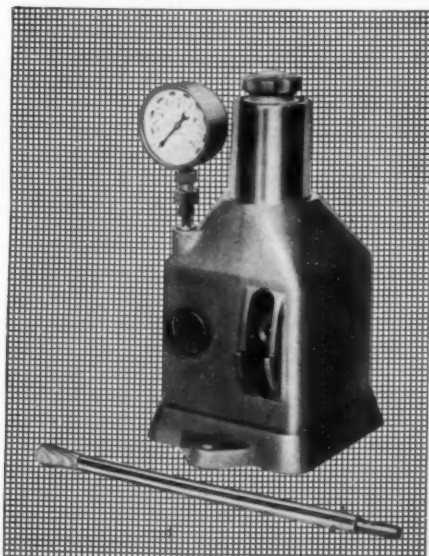
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**GOOCH STREET, BIRMINGHAM, 5.**

SM/IP.962d

## Nash and Thompson Metallurgical Mounting Press



A machine for the quick mounting of specimens for metallographic work, based on the press designed by the British Non-Ferrous Metals Research Association.

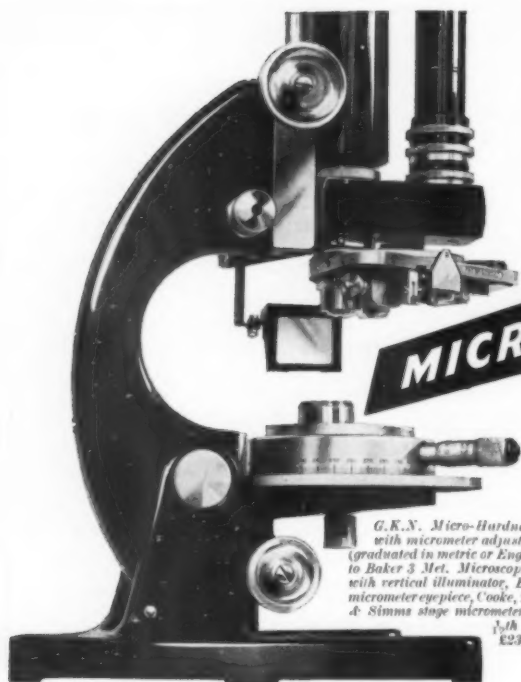
The press is available with cylinders diameter 1 in. 1 1/4 in. and 1 3/4 in. These are mounted with the ram in a single unit so that the mould can be formed and ejected with an axial force.

The heating element is rated at 600 watts to give a reasonably quick rate of working, and a water cooling coil is built in to the cylinder wall. Moulds up to 2" deep can be produced in approximately ten minutes. 10" x 12" x 18" high. Weight 76 lbs.

Write for a leaflet giving full details of this instrument, which is available for quick delivery. It is also available for hire.

*Nash and Thompson will design and make special instruments for any purpose, singly or in small batches. The company specialises in instruments to do something out of the ordinary for industry*

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# LABORATORY METHODS

MECHANICAL • CHEMICAL • PHYSICAL • METALLOGRAPHIC

INSTRUMENTS AND MATERIALS

JULY, 1954

Vol. L, No. 297

## A Method for the Electrolytic Etching of Aluminium for Microscopic Examination

P. A. Raine, F.R.I.C., H. J. Ellis, B.Sc., A.R.C.S., and L. W. Terry

**D**EVELOPMENT and control work in connection with the manufacture of aluminium sheathed cables involves the study of the structure of extruded aluminium tube at all stages of the extrusion cycle. The material employed in current practice is usually Grade T.1B aluminium of 99.5% purity, or better, and a technique was required applicable to large sections of tube (up to about 4 in. in diameter) on this metal which would clearly delineate:—

- (a) grain size and structure;
- (b) transcrystalline flow lines characteristic of the extrusion cycle;
- (c) intercrystalline defects (voids, laminations and inclusions) indicative of faulty extrusion.

It soon became evident that the usual chemical etching reagents of the acid or alkaline type could not be relied upon to fulfil all these requirements. In particular, it was found that such chemical methods of etching, when applied to areas of metal greater than a few square millimetres, were liable to give uneven results and produce local pitting on parts of the surface. While they could be used for the preparation of surfaces for macro-examination, they were generally of little value if a magnification exceeding twenty times were to be used in examining the section.

Accordingly, attempts were made to use an electrolytic method, following Servi & Grant.<sup>1</sup> These workers use a reagent containing 5 ml. of perchloric acid (72%) in 95 ml. glacial acetic acid; polishing is carried out at 25–60 volts and etching of coarse-grained specimens at voltages below 10. Starting from this basic information, a number of variations have been tried in the light of working experience. The development of the method was essentially empirical, and at the present time several variations of technique are used according to the end

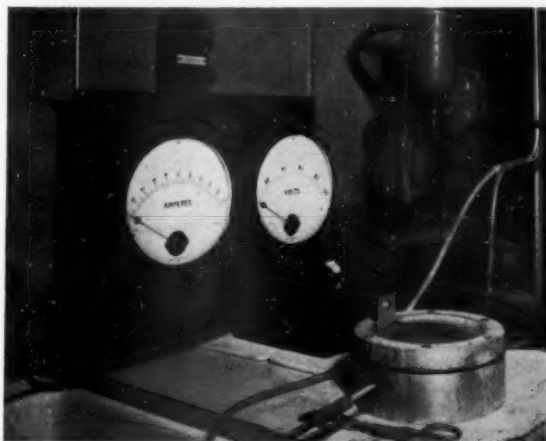


Fig. 2.—Etching apparatus.

results desired, e.g., visual examination or photography at various magnifications.

### Experimental Details

#### Preliminary Treatment.

Samples are usually received in the form of tube, but other types (e.g., flat strip) may also be encountered. Tube samples may be cut off using a milling machine to produce a smooth surface in one operation or, alternatively, cut with a hacksaw and smoothed by turning in a lathe, or by filing. Normal grinding procedure is followed, using 2/0, 3/0, and 4/0 emery paper flooded with paraffin; final polishing is carried out on a wheel covered with Selvyt cloth using metal polish, with water containing a wetting agent as lubricant.

#### Etching Apparatus.

The circuit of the apparatus at present in use is shown in Fig. 1, and its general arrangement in Fig. 2. Cell dimensions were selected to enable work to be carried out on specimens up to about 5 in. in diameter. The cell proper consists of a glass petri dish, with a cathode of sheet aluminium covering the bottom; this vessel is held in a recess turned in the upper aluminium disc of the cooling block. Water is circulated through the lower part of the block, which is bolted to the upper

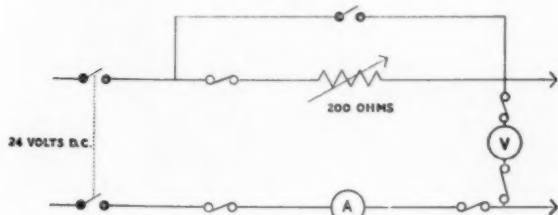


Fig. 1.—Circuit diagram of etching cell.

<sup>1</sup> *Journal of Metals*, 1951, June, 3 (6), 473.

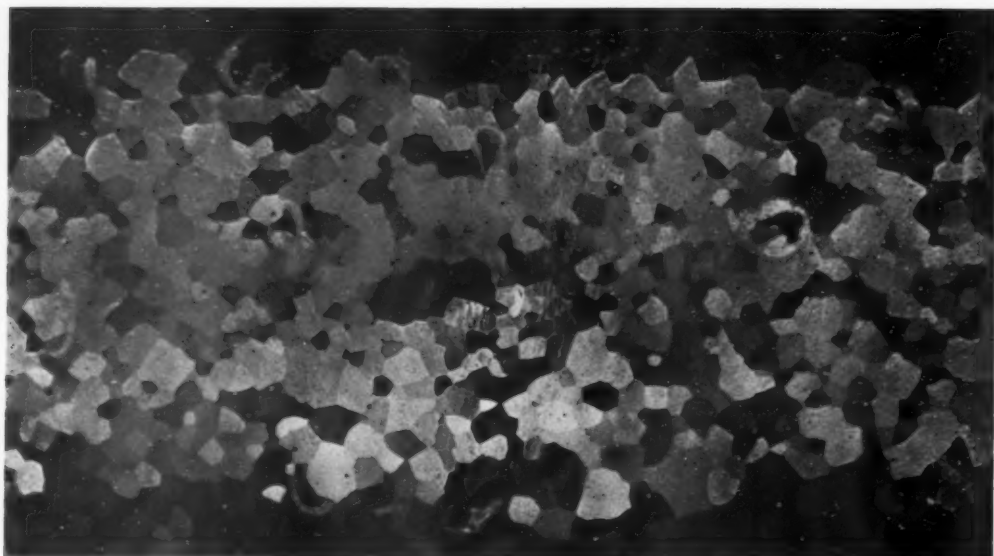


Fig. 3.—Photomicrograph of clean seam showing traces of flow lines.  $\times 45$

disc and the joint sealed with a neoprene gasket. In earlier work the aluminium disc was used as the cathode, but after some months service it became porous.

#### Reagents.

The reagents used are mixtures of perchloric acid (72%) and glacial acetic acid in proportions varying from 1 to 5% perchloric acid. The solution usually employed contains 2½% perchloric acid, but the lower concentration of 1% is of value in showing up some extrusion features. No trouble has been encountered due to overheating or explosion of the reagent, but an efficient fume extraction system is essential; temperature does not appear critical but should be maintained below 20° C.

#### Procedure.

The polished sample is washed and dried under a hot air blast. It is then held (by insulated tongs connected to the positive side of the circuit) face downwards in the reagent and allowed to polish with an applied potential of 24 volts for 3–5 seconds. Without removing the sample,

the voltage is reduced by switching in the variable resistor and etching allowed to take place for a further 3–5 seconds; the resistor is momentarily switched out of circuit and back again and the sample removed from the cell. If the etch does not appear satisfactory the sample may be returned to the cell and the "flashing" operation repeated once or twice. When a satisfactory etch has been obtained the sample is washed and dried for examination.

In the case of cold worked samples it is necessary to reduce the polishing time in order to retain the grain structure and some variation of etching time may be called for.

It has not been found possible or desirable to lay down a rigidly standardized technique, owing to the large number of variables involved. The age and condition of the reagent have a great influence on the type of surface produced; for example, freshly prepared reagent normally requires considerable working before good results

*Continued on page 52*



Fig. 4.—Inclusions at the interface between two metal streams.  $\times 140$

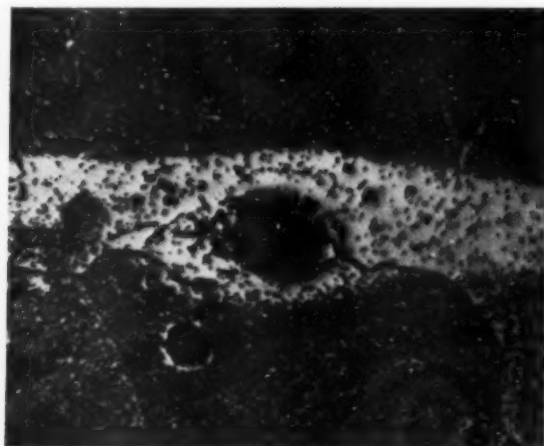


Fig. 5.—Grain boundary inclusions.  $\times 860$

# New Facilities for Aluminium Laboratories, Ltd.

## Extensions at Banbury Completed



The main facade showing on the extreme right part of the new office-and-laboratory wing.

WITH the recent completion of the new extensions, the floor area of the Banbury premises of Aluminium Laboratories, Ltd., has been more than trebled—from 21,000 sq. ft. in 1951 to 65,000 sq. ft. to-day. This company, which is a wholly owned subsidiary of Aluminium, Ltd., conducts basic and applied research in the light metal field, and engages in the investigation of technical problems in the fabricating and sales fields for the benefit of the Aluminium, Ltd., Group of Companies—including Northern Aluminium Co., Ltd., the largest fabricating unit in the Group, and Aluminium Union, Ltd., the international trading company.

The parent company is responsible for approximately one-quarter of the world output of primary aluminium, and one of the most important aspects of the work of Aluminium Laboratories, Ltd., is concerned with the extraction side of the industry. The Montreal headquarters of the Company co-ordinates all exploration and geological surveys which are carried out, and acquires on behalf of Aluminium, Ltd., rights to mineral resources, and to electric power when necessary. The Montreal Engineering Department is engaged in the design of plant and equipment for every phase of the business, and keeps an active interest, on behalf of the operating companies, in developments in new equipment and techniques for the extraction and fabrication processes.

At Arvida, in Northern Quebec, a laboratory adjacent to one of the Aluminum Company of Canada's principal smelters carries out research into all the problems of ore treatment and extraction of the metal, whilst the laboratories at Kingston (Ontario) and Banbury are mainly concerned with the development of techniques for the fabrication and use of aluminium. They are closely linked with fabricating works of members of the Group—Aluminum Company of Canada at Kingston, and Northern Aluminium Co., Ltd., at Banbury. An office in Geneva is concerned with the fundamentals of design for structural applications.

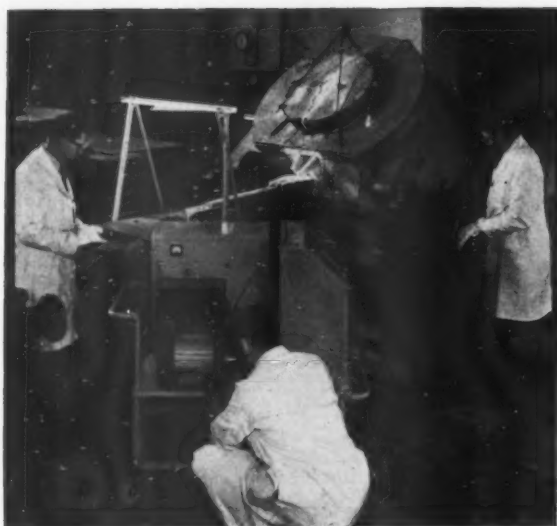
The work of Aluminium Laboratories, Ltd., can be summarised under two main headings: research and

technical service and development in support of the operating companies of Aluminium, Ltd. A Patents and Agreements Department in Montreal and Banbury provides a patents service and negotiates all matters concerned with the reciprocal use of technical processes by associated and other companies, and a large technical library has been established which is available for consultation by all associated companies. Parallel with the publication at the laboratories in Kingston of a monthly abstract bulletin containing summaries of references to aluminium in the world's technical press, a similar service at Banbury provides statistical and economic data pertaining to the industry.

As part of the technical service provided by Aluminium Laboratories, Ltd., a Liaison Division exists at both Kingston and Banbury to assist and channel the interchange of information between fabricating companies. Some of this information operates in a routine manner by distribution of specifications, but often more detailed investigation is needed, and it is sometimes desirable to arrange visits by specialists from one associated company to another. Liaison is also maintained with companies operating Aluminium, Ltd., processes under licence, or who have authorised a member of the Group to use their processes.

### The Research Department

The Research Department is divided into four main Divisions: Chemistry, Metallurgy, Physics and Engineering. The work of these different divisions often overlaps, and any particular problem, while being the responsibility of a particular division, may need the co-operation of several others, the individuals engaged in the work operating as a group. Each group maintains a very close liaison with other specialists, at universities and elsewhere, who are working in the same field. The research programme is frequently reviewed with representatives of the fabricating plants, particularly with the Northern Aluminium Co., Ltd., with the aim of ensuring that practical aspects are kept in mind, notwithstanding the long-term nature of some of the research work.



High speed temperature recorder in use for determining temperature distribution in a continuously cast aluminium billet.

### Metallurgy Division

The Metallurgy Division is concerned with long-term research into the metallurgy of aluminium, with particular emphasis on fabrication and utilisation problems, although a large proportion of its work is also directed to practical metallurgical problems of immediate importance to associated companies. The Division has four sections, dealing with casting, working and physical metallurgy, alloy development, and corrosion.

In view of its importance to the subsequent fabricating operations, it is not surprising that the principal interest of the Casting Section is in the study of the casting of ingots and billets. The foundation for this work is a study of the freezing mechanism, and of the thermal conditions during solidification. This work is followed by an assessment of the effect of variation in thermal conditions on the metallurgical structure, and of this structure on the behaviour during working and on the properties of the finished product.

Parallel with investigations of casting is the study of the effect of composition on the mechanical and fabricating properties of material used in the wrought condition. This work is being carried out by the Wrought and Physical Metallurgy Division, which is equipped with experimental rolling mills and associated ancillary equipment, heat treatment plant, and a metallurgical laboratory. Research into the properties of sheet products requires an investigation into the generation of textures throughout the fabricating processes, both by statistical analysis of works data, and by laboratory investigations of the effect of fabrication conditions.

No doubt the work of the Corrosion Section has considerable interest for the Chemistry Division as the subject is one in which the metallurgist and the chemist are equally concerned. In addition to collecting and correlating information on the behaviour of aluminium alloys exposed to different environments, fundamental work on the corrosion resistance and electrochemical behaviour of alloy systems is carried out by the Section, in parallel

with other work on the same systems. Exposure stations for corrosion testing are maintained in a wide range of environments in many parts of the world, and laboratory facilities are available for testing in salt spray, and in hot humid conditions.

Planned on a long-term basis, the work of the Alloy Development Section is concerned with the application of modern theories of metal physics to the design of alloys, and in this respect acts as a feeder of information to the wrought alloy metallurgists, who are more concerned with practical metallurgical problems.

### Engineering Division

The Engineering Division also is divided into four sections, each responsible for a particular branch of engineering related to the production and use of aluminium alloys. The Metal Deformation Section, as its name suggests, investigates problems of hot and cold working of aluminium, and provides data from which the behaviour of the metal under these conditions can be predicted. Much of the research now in hand is concerned with the application of plasticity theory to metal working operations, whilst a study being made in conjunction with the Chemistry Division aims at elucidating the role played by lubrication in such processes. The Section is also concerned with the study of the formation and effects of residual stresses in aluminium alloys arising from such operations as quenching.

Studies providing a theoretical treatment of structural design problems are the responsibility of the Structural Engineering Section, and much of this work will appear in the form of design handbooks issued by associated companies. Practical work on structural design is carried out in the structural testing laboratory, where facilities are available for load tests on structures up to 40 ft. long  $\times$  7 ft. 6 in. wide.

Information, derived by standardised test methods, is provided by the Mechanical Properties Section for use in data sheets and technical handbooks published by associated companies. This Section is also responsible for carrying out the more complex tests necessary for the study of practical problems such as fatigue.



Salt spray corrosion testing room.

Lastly, the Mechanical Engineering Section, which includes a drawing office and machine shop, provides a general service for the development of machinery and equipment, and also prepares the standard test pieces for mechanical, physical and corrosion testing.

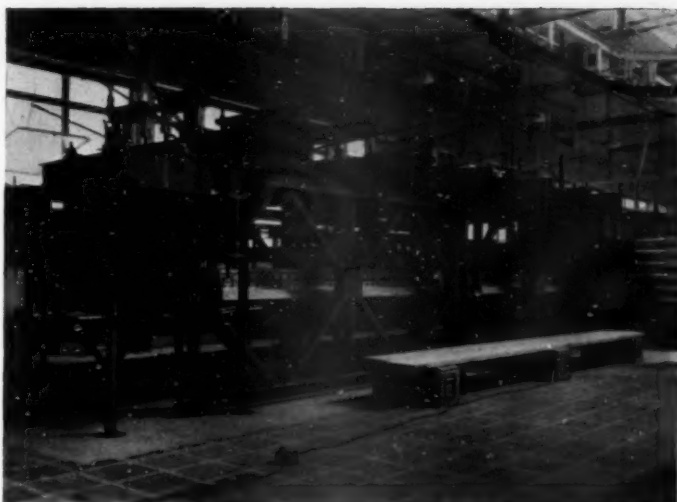
### Physics Division

The work of the Physics Division includes the compilation of physical data on aluminium, the practical application of physical methods to research investigations, and the provision of an instrumentation service for the laboratories and fabricating companies.

The Metal Physics Section has three laboratories, devoted, respectively, to metal physics, X-ray work and creep testing, and much of the work in progress is closely related to that of the Physical Metallurgy Section of the Metallurgy Division. The main object of the work is the provision of a background of information on the physical characteristics of aluminium alloys, on which other divisions can draw for use in the solution of problems directly connected with fabrication and sales. The Section is engaged on investigations concerned with the study of recrystallisation characteristics; work- and precipitation-hardening; effect of constitution and structure on basic physical properties; the properties of aluminium surfaces, and of surface treatments; and the elastic and plastic deformation of aluminium alloys.

The work of the Applied Physics Section involves the application of known physical principles to the improvement of fabrication processes, and to the problems arising in fabrication and utilisation. In general, the greater part of the work of the Section is concerned with problems of electricity and magnetism; and with heat transfer.

Two branches of instrumentation have become of major importance to the Group: pyrometry and non-destructive testing. Work in the former field is at present concerned with the rapid and accurate measurement and



Proof bending test on prototype aluminium hatch cover.

recording of temperature, whilst the Instrument Section's activities in non-destructive testing are mainly in the ultrasonic and electromagnetic fields. In addition to these two main items, the Section is always meeting demands for specialised instruments, such as apparatus for the continuous gauging of strip; automatic recorders for proof stress and elongation in tensile testing; and instruments for the automatic rejection of defective semi-finished products.

### Chemistry Division

The Chemistry Division conducts research into the chemistry of aluminium, and renders service to other divisions by the provision of chemical data. The Al-paste, Lacquers and Surface Chemistry Section is principally concerned with the chemistry of aluminium surfaces, but also deals with all problems affecting surface finish. The study of the properties of the oxide film, of methods of reinforcing or thickening it by anodising or chemical dips, or of removing it to obtain adherent electroplated coatings, are important aspects of the Section's work. Problems associated with the use of working lubricants are also of interest to the Section, as are those concerned with protective lacquers and paints, and with the production of aluminium paste as a pigment for paint.

The remaining branch of the Chemistry Division is the Analytical and General Chemistry Section, which is responsible for providing information on the composition of materials under investigation. The work calls for a comprehensive knowledge of analytical techniques, including semi-micro methods for use with, for example, corrosion deposits. In addition to the analytical work, problems requiring a chemical approach are handled in this Section, recent examples including the selection of a suitable strong alloy for a pump to handle fuming nitric acid, and a study of the complex organic hydroxy-compounds in rubber latex.



The creep testing laboratory.



Anodising in the surface finishing laboratory.

### Technical Service and Development

Working closely with the Research Department is the Technical Service and Development Department, which serves associated companies by the provision of technical service, by design and development work, and by the production of publications.

### Technical Service and Project Division

On request, the Technical Service and Project Division provides technical opinions and practical assistance in problems of joining, surface finishing and metal working, including the investigation of established and new processes and advice on the plant required. It will also provide a day-to-day technical sales advisory service in the application of Aluminium Laboratories' research activities. This Division also co-ordinates, on behalf of associated companies, the study of those projects which require the co-operative effort of both development and research. For example, the development of an aluminium food can has occupied the attention of this division



Prototype aluminium freight container for British Railways.

for some time, during which problems such as deep drawing of containers, the high-speed stoving of lacquers, and the development of suitable alloys have been solved.

### Design Division

The Design Division provides on request a general design service and drafting facilities in support of associated companies, or of Aluminium Laboratories' specialists engaged on project development. It is also responsible for work on the long-term technical problems associated with the use of aluminium in structural applications.

### Publications Division

The Publications Division is responsible for the preparation on request of illustrated manuscripts, technical articles, bulletins and lectures, whereby selected results of the Laboratories' work can be made available to associated companies for use by them in support of sales or general publicity. The compilation of photographic records is also handled by this Division.

### The New Buildings

The original premises of Aluminium Laboratories, Ltd., at Banbury, were completed in 1938. After the war they were found inadequate for the increased volume of research which had become necessary due to the expansion of the industry during the war, and the extensions which have been completed this year were put in hand. The architects were Sir Percy Thomas & Son, of Cardiff.

The premises now consist of four blocks; the original building which faces the main road, and is now given over mainly to administrative offices; the executive wing with the library above; the long northern wing which contains most of the laboratories and the offices appertaining to them; and the large, high, single-storey laboratories and experimental blocks which flank the other three sides of the western courtyard.

The north wing, which houses the main laboratories, has several interesting features. It is built in bays of 12 ft. 6 in., sub-divided on a 3 ft. 1½ in. module, and this allows the office or laboratory size to be easily changed, merely by moving the Holoplast partitions. The north wall of the asymmetric central corridor is of double construction, and provides a duct from floor to floor for the numerous services to the laboratories. This duct links with a crawlway running the length of the building and connecting with the boiler house, electric switch-room and other services.

The new building is heated by the Frenger system, which comprises low-pressure hot-water pipes suspended from the ceiling, and fed from three oil-fired boilers. To these pipes are clipped two-foot-square aluminium radiant panels which are continuous over the whole ceiling, allowing all the floor-space to be made available for laboratory and other requirements, in addition to providing acoustic correction. Aluminium windows are fitted throughout, those in the executive wing being double glazed. Among the many uses of aluminium in the buildings are the trusses and roof cladding in the experimental block, roof ladders, conduit, balustrades, ventilators, venetian blinds, and metallic trim.

All the laboratories are provided with fresh air from which the dust has been removed by filtering. Where necessary, fume cupboards and hoods have been provided, and full air conditioning is in force in the salt spray room

and the stress corrosion laboratory, where careful control of temperature and humidity is necessary.

Each laboratory is provided with hot and cold water, distilled water (through super-purity aluminium pipes), compressed air at 80 and 20 lb./sq. in., vacuum and gas.

These are fed direct into the false backs of the teak-topped laboratory benches. In addition, the following electricity supplies have been made available in the laboratories which require them: 230-volt A.C., D.C., and constant voltage A.C.; 110/60-volt A.C.; 72-volt D.C., 12/24-volt D.C. and 2-volt D.C.

## Exhibits of Metallurgical Interest at the Physical Society Exhibition

*The exhibits at the Physical Society's annual exhibition of scientific instruments usually include a number of interest to workers in the metallurgical field. This year was no exception and in this issue we continue a short series of reviews in which such items will be described.*

### Industrial Television

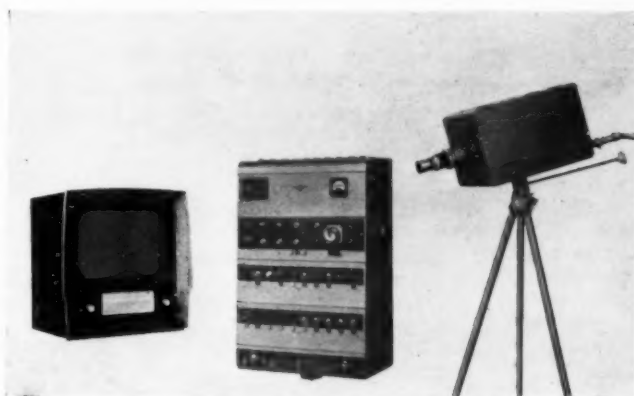
**T**ELEVISION for remote observation in industry, commerce, research and education, may compete in importance with television as an entertainment medium. The research organisation of Electric & Musical Industries, Ltd., has now developed high definition equipment in a form suitable for general use, which provides a means of remote observation of any number of objects or operations, either separately or simultaneously, under difficult or dangerous physical conditions. It acts, in fact, as a substitute for the human eye.

A small camera can be placed in inaccessible positions or used to watch processes involving high temperatures or personal danger. Moreover, the errors in readings which can arise in conventional methods of remote metering are eliminated by using television for this purpose. Furthermore, in many instances, economy of personnel may be effected by employing more than one camera in order to view several different scenes from one central observation point.

Specific applications in industry include the control of dangerous foundry and rolling mill processes; observation of hazardous milling and machining operations; inspection of inaccessible places such as gun barrels, insides of tanks and cylinders, castings, and factory chimneys; remote reading of dials and gauges in dangerous and difficult positions; viewing tests involving high temperature, voltage, speeds or other personal dangers; and control panel observation of the actual conditions inside furnaces and chimneys. On the research side, the equipment is suitable for all types of telemetering; counting minute objects; very close or lengthy observation of experiments; and viewing experiments involving possible explosions, radioactivity and other hazards.

The equipment may also be used in many fields outside industry, especially in commercial work, education and training; for example, students at the rear of a large class may be brought within inches of the object being demonstrated, without moving from their seats; and offices, laboratories and banks can check written and printed matter over considerable distances.

Besides the general equipment, a specialised development was demonstrated at the exhibition. This involves the use of a specially developed Emitron camera tube, sensitive to ultraviolet wave lengths down to 2,000



E.M.I. industrial television equipment.

Angströms, for viewing images of biological specimens produced by an ultraviolet microscope, and thereby eliminating the considerable strain involved in conducting a minute examination of a specimen in the conventional manner. There is the further advantage of mass observation of the specimen, if required.

### The Two-Image Pyrometer

It is most important for designers and operators of open-hearth furnaces to know the properties of the flames used to bring the furnaces to their working temperatures. The B.I.S.R.A. two-image pyrometer makes possible, for the first time, the continuous measurement of radiation, emissivity, and temperature of flames in the open-hearth furnace. Neither the conventional Schmidt method, nor the technique developed out of it in an experimental furnace by the International Flame Radiation Research Committee at IJmuiden, Holland, have provided for the continuity of measurement which is necessary for a study of the effect of variables such as the ratio of steam to oil, and the ratio of air to fuel, on the output of the furnace.

The essence of the Schmidt method is measurement of the radiation from the flame, together with the measurement of the amount of radiation absorbed by the flame from another standard radiator placed behind the flame. In the IJmuiden experimental furnace, vertical slots were made in the walls on opposite sides of the furnace,

so that a radiation pyrometer sighted through one slot would "see" right through the flame to the other side. The pyrometer, enclosed in a water-cooled case, was of the off-axis type, with a mirror, which reflected the energy of the flame at a small angle onto a receiving thermopile. The inside surface of the furnace wall opposite the pyrometer was used as the standard radiator. When the radiation from the flame alone had been measured, the pyrometer could then be turned through a small angle to measure the combined radiation of the flame and wall.

For steelworks operation, the turning operation would be impracticable, and in any case breaks the continuity. The mirror reflecting off-axis radiation pyrometer has, therefore, been adapted to receive two images. The thermopile receiving the reflected energy has two separate junctions, each situated so as to receive a separate image. The junctions are connected to separate channels of a multipoint recorder and a simultaneous measurement can then be made.

### Ultrasonic Thickness Gauge

There are many instances when it is required to measure wall thickness of material when one surface is inaccessible. The Dawe Ultrasonic Thickness Gauge, which is an apparatus for measuring the thickness of materials by means of high frequency sound waves, has been specially developed for just such applications. Two models are available: the Type 1101, and the Type 1101/1.

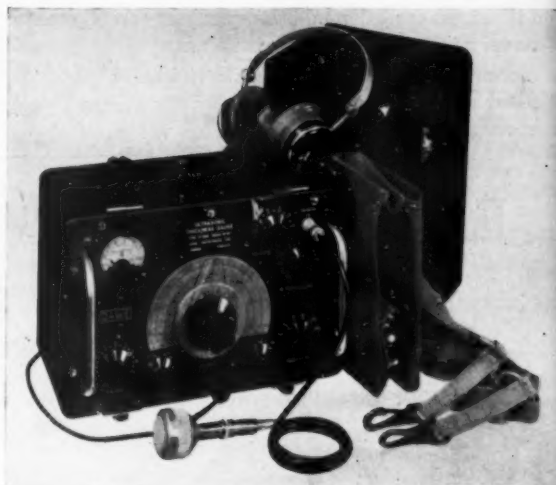
The ultrasonic thickness gauge measures thickness from one side by determining the fundamental natural frequency of vibration in the thickness direction. This natural frequency is essentially independent of the other physical dimensions of the material.

A vibrating quartz crystal is placed in contact with one side of the material under test, so that an ultrasonic wave is transmitted into the material. This wave travels in a narrow beam through the material and is reflected by the opposite surface. At certain frequencies, when the transmitted and reflected waves are in phase, there will be a relatively large increase in the amplitude of the wave in the material. This is a resonance condition occurring at the fundamental frequency and harmonics of the fundamental frequency.

The fundamental resonance frequency is inversely proportional to twice the thickness, and directly proportional to the velocity of sound in the material, which is known for most materials or can be determined by the equipment from a sample. Thus the thickness can be determined.

By frequency modulating the quartz crystal drive oscillator at an audio rate, a signal is produced at the fundamental frequency and at harmonics of the fundamental frequency. This signal is heard in a set of headphones, and is simultaneously indicated by an increase in the deflection of a panel millimeter. The difference frequency between any two adjacent signals measured on the scale gives the fundamental resonant frequency. A conversion scale on the instrument panel shows the thickness corresponding to the measured frequency difference. The standard Ultrasonic Thickness Gauge Type 1101 covers the frequency range 0.65 to 2 Mc/s and the thickness range of steel, for example, which can be measured is from approximately 0.6 in. to 12 in.

The H. F. Ultrasonic Thickness Gauge Type 1101/1 equipment extends the range for steel down to 0.02 in.



Dawe ultrasonic thickness gauge.

by using higher ultrasonic frequencies in the range 2 to 6 Mc/s, and provides improved accuracy over the Type 1101 equipment when measuring thin materials in the range 0.06 in. to about 0.2 in. Due to the higher frequency, the ultrasonic wave is more rapidly attenuated by surface irregularities, and the attenuation of the ultrasonic wave becomes appreciable, particularly with thick materials. Thus the high-frequency model is primarily intended for tests on thin materials with relatively smooth surfaces, although under favourable conditions materials several inches thick can be measured. However, in general the standard equipment is recommended for measurements exceeding about 0.25 in. of steel.

The type 1101 model is mainly used for the corrosion inspection of pressure vessels, pipes, tanks, ships' hulls, etc.; for the inspection of new fabricated parts with a thickness greater than 0.25 in., and for spot checking for lamination. For the inspection of new materials between 0.020 in. and 4.0 in., where a wide thickness range is essential, the Type 1101/1 H.F. model is used; also for the corrosion inspection of thin materials where pitting is not very severe, including boiler tubes, and copper and stainless tubing.

### Electrolytic Etching of Aluminium

*Continued from page 46*

are obtained, but a solution prepared a few days before may reach a satisfactory condition after very little use. Experience is the best guide in this respect.

Photographs of sections of aluminium tube prepared by the method described are shown in Figs. 3-5. Fig. 3 shows a clean seam area, outlined by a pattern of "flow" lines, whilst Figs. 4 and 5 show small inclusions at grain boundaries at two different magnifications. Fig. 5 shows the tiny etch pits which are formed during treatment; they do not interfere with normal examination of sections, and indeed only become distinguishable at higher magnification.

### Acknowledgments

This work was carried out in the Laboratories of Messrs. Johnson and Phillips, Ltd., and the authors are indebted to the Directors of the Company for permission to publish this communication.

